FOCUSED FEASIBILITY STUDY

ALASKA REAL ESTATE PARKING LOT
4th and Gambell
ANCHORAGE, ALASKA

NTP 18-4002-11-041

PRELIMINARY DRAFT
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Prepared for:

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ACRONYMS AND ABBREVIATIONS

ADEC .... Alaska Department of Environmental Conservation
bgs .... Below ground surface
CERCLA........ Comprehensive Environmental Response, Compensation and Liability Act
CHP............... Catalyzed hydrogen peroxide
CSM .... Conceptual site model
cm/sec........... centimeters per second
cy................... Cubic yards
cDCE............. cis-1,2-Dichloroethene
DO................. Dissolved oxygen
EPA............... Environmental Protection Agency
ERD............... Enhanced reductive dechlorination
FS.................. Feasibility study
ft/ft .... Feet per foot
gpm .... gallons per minute
HRC™........... Hydrogen Release Compound
IDC .... inhalation/direct contact pathway (cleanup levels)
ISCO .... In-situ chemical oxidation
µg/L .... Micrograms per liter
µg/m^3............. Micrograms per cubic meter
mg/kg .... Milligrams per kilogram
m/s .... meters per second
MNA .... Monitored natural attenuation
MTG .... Migration to groundwater (cleanup levels)
NCP............... National Contingency Plan
ORP .... oxidation-reduction potential
PCE............... Tetrachloroethene
ppbV.............. parts per billion by volume
RAO .... Remedial action objective
RCRA............ Resource Conservation and Recovery Act
SI................... site investigation
SVE............... Soil vapor extraction
TOC............... total organic carbon
TCE............... Trichloroethene
USCS .... Unified Soil Classification System
VI................... vapor intrusion
VMP .... Vapor monitoring point
VOC .... Volatile organic compound

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1. PURPOSE AND EXECUTIVE SUMMARY

The purpose of this focused feasibility study (FS) is to evaluate remedial alternatives for addressing contaminated soil and groundwater at the Alaska Real Estate Parking Lot site located in Anchorage, Alaska. The Alaska Real Estate Parking Lot property is owned by Fourth Avenue Gambell Associates LLC that presently use the site as a parking lot. The property was previously occupied by a variety of businesses, including C&K Cleaners (a dry cleaner) from approximately 1968 to 1970, and NC Tire Center (vehicle service center) from 1976 to 1978. By 1978 all of the buildings located on site were demolished and the site was converted to a parking lot.

Soil, soil gas, and groundwater at the Alaska Real Estate Parking Lot site are contaminated by the chlorinated solvent, tetrachloroethene (PCE) and its degradation products, trichloroethene (TCE), cis-1,2-dichloroethene (cDCE), and vinyl chloride (VC). This contamination has resulted in VOC concentrations exceeding the Alaska Department of Environmental Conservation (ADEC) 18 AAC 75 cleanup levels for soil and groundwater, and 18 AAC 80 drinking water maximum contaminant levels (MCLs). This contamination also contributes to exceedances of ADEC Target Levels for indoor air.

The only remedial or protective actions that have been taken were the installation of two submembrane depressurization (SMD) systems in the crawls spaces for the North and South Duplex at 736 East Third Avenue (OASIS, 2010b). The SMD systems were installed by a former property owner (Mark Cupples) between the March and June 2009 vapor intrusion sampling events to address indoor air exceedences for PCE from the March 2009 crawl space samples. ADEC continued to monitor the crawl space air at both of these duplex locations during vapor intrusion sampling events performed in June 2009, February 2010, and May 2010. The June 2009 crawl space results for the South Duplex were below ADEC indoor air target level but all remaining crawl space air sample results from the duplexes have been above the ADEC indoor air target level of 4.1 $\mu g/m^3$ for PCE (note ADEC October 2012 Vapor Intrusion Guidance revised this level to 42 $\mu g/m^3$ for PCE that only the North Duplex exceeded). An inspection of the SMD revealed numerous liner penetrations and gaps that are contributing to the ineffectiveness of these SMD systems (OASIS, 2010b).

This Focused FS presents a summary of the historical analytical results for the site, a discussion of the nature and extent of soil and groundwater contamination, five remedial alternatives for addressing each soil and groundwater contamination, and an comparative analysis of the alternatives. The five alternatives for soil are listed below with their estimated remedial timeframes.

- Alternative S-1: No Action (infinite remedial timeframe)
- Alternative S-2: Soil Vapor Extraction (SVE) (10-year remedial timeframe)
- Alternative S-3: In-Situ Chemical Oxidation (ISCO) (5-year remedial timeframe)
- Alternative S-4: In-Situ Thermal Remediation (ISTR) (5-year remedial timeframe)

- Alternative S-5: Soil Excavation (xx-year remedial timeframe)

The five alternatives for groundwater are listed below with their estimated remedial timeframes.

- Alternative GW-1: No Action (infinite remedial timeframe)
- Alternative GW-2: Monitored Natural Attenuation (MNA)/Long-Term Monitoring (LTM) (35-year remedial timeframe)
- Alternative GW-3: In-Situ Chemical Oxidation (ISCO) (10-year remedial timeframe)
- Alternative GW-4: Enhanced Reductive Dechlorination (ERD) (20-year remedial timeframe)
- Alternative GW-5: Permeable Reactive Barrier (30-year remedial timeframe)

The five alternatives were evaluated against the nine criteria described in Section 121(b) of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and the National Contingency Plan (NCP) §300.430(f)(5)(i). Results of the comparative analysis are summarized below in Table 1-1. The two “threshold criteria” must be met in order for an alternative to be considered for selection; therefore, “yes” and “no” were used as the scores for these criteria. A numerical scoring scheme was used for evaluating the five balancing criteria. Each alternative was assigned a numerical score between 0 (worst) and 5 (best) for each criterion to reflect the expected performance of the alternative. The scores have no independent value; they are only meaningful when compared among the different alternatives.

TABLE 1-1: COMPARISON OF REMEDIAL ALTERNATIVES

Remedial Alternative		Threshold Criteria		Effectiveness Scores				Cost				
Identifier	Description	Protection of Human Health and the Environment	Compliance with ARARs	Long-term Effectiveness and Permanence	Reduction in Toxicity, Mobility, and Volume through Treatment	Short-term Effectiveness	Implementability	Cost Score	Estimated Present Worth Range (-50% to + 100%) (in thousands of dollars)	**Effectiveness Total**	**Total Score**	**Effectiveness to Cost Quotients**
Groundwater Alternatives												
GW-1	No Action	No	No	0.0	0.0	0.0	5.0	5.0	\$0 \$0	0.0	10.0	NA
GW-2	LTM/MNA	Yes	Yes	2.0	2.0	3.3	4.0	2.2	\$1,217 \$4,870	7.3	13.5	0.60 0.15
GW-3	ISCO (Chemical Oxidation)	Yes	Yes	4.0	4.0	2.5	3.0	0.0	\$2,152 \$8,608	10.5	13.5	0.49 0.12
GW-4	ERD (Substrate Addition)	Yes	Yes	3.5	3.0	3.3	3.0	1.0	\$1,715 \$6,858	9.8	13.8	0.57 0.14
GW-5	Air Sparging	Yes	Yes	2.5	2.0	2.5	2.0	0.8	\$1,813 \$7,252	7.0	9.8	0.39 0.10

Explanation of Scores:

0 Worst (Criterion not satisfied)
1 Poor
2 Below Average
3 Average
4 Above Average
5 Best (Criterion completely satisfied)

Preferred Alternative

Selection of a preferred alternative depends on the relative importance of the variables. GW-2 (MNA) and GW-4 (ERD) are the most cost-effective alternatives; ERD has a higher effectiveness than MNA, but the increased effectiveness is countered by its higher cost. If achieving cleanup in the shortest time is the most important factor, then Alternative GW-3 (ISCO) is preferred, although it is also the most expensive alternative. Air sparging has the lowest total score and effectiveness to cost quotient and is least likely to be considered the preferred alternative.

Overall, it appears that additional plume characterization and implementation of the soil remedies would be beneficial before selecting a groundwater remedy. Additional plume characterization activities should include installing soil borings and monitoring wells east of the Aniak Middle School building, west of the building in the vicinity of SGP-17 and SGP-18, and in several other locations as needed to complete characterization of both plumes and the silt layer. MNA parameter monitoring should be performed at low water level. Microbial community testing for dehalococcoides organisms should be performed. Use of Bio-Trap® in-situ microcosms may be a cost-effective technique to assess the MNA potential, native microbiological community, and expected performance of substrate amendment. During the PCB soil excavation in the vicinity of the former septic tank and truck fill, soil samples should also be analyzed for TCE. If high TCE concentrations are detected in the silt at the base of the PCB excavation, overexcavation of TCE-contaminated soil or direct treatment using a reductant (or possibly an oxidant) during the PCB soil excavation may be a very beneficial and cost-effective remediation strategy. Alternatively, depending on the location, magnitude, and extent of the TCE contamination and silt characteristics, installation of an engineered solution, such as placement of a gravel layer at the base of the excavation with distribution piping and a standpipe at the surface that could be used to deliver reagents periodically, may be warranted. Sampling details and a decision protocol should be incorporated into the excavation work plan.

Based on existing data and weighing the effectiveness and cost considerations, Alternative 2 (MNA) or Alternative 4 (ERD) may be considered preferred. MNA would be expected to perform satisfactorily at this site if the following conditions are met. The conditions are based on a decision flowchart for MNA and enhanced attenuation presented in (ITRC, 2007).

1. Additional site characterization confirms that there is no distinct source/primary plume in the saturated zone. There is no evidence of free-phase or residual-phase TCE, and maximum groundwater concentrations remain three-to-four orders of magnitude below the solubility limit. The groundwater plume configuration is generally as outlined in this FS.
2. Additional groundwater monitoring supports the conclusion that the plume is stable.
    a. The groundwater plume is stable or shrinking, and there is no risk to the nearby drinking water wells. An alternative point of compliance can be established downgradient of the source area.
    b. The PCB soil excavation and SVE adequately address vapor intrusion risk (i.e., most of the contaminant mass is in the vadose zone). Although volatilization from the silt layer/saturated interval below the silt layer may provide a continuing source for soil gas contamination, the level of continued volatilization is currently unknown and may be minor, especially if the upper portion of the silt layer is directly treated during the PCB soil excavation.
    c. Future VOC and geochemical parameter sampling indicates that there are zones or areas of highly-reducing groundwater in which reductive dechlorination of TCE is occurring at sustainable rates to adequately remediate the contamination over time.
    d. This alternative is deemed acceptable to ADEC and all of the interested parties.
3. If the above criteria are not completely satisfied, then it may be advantageous to implement ERD in a phased approach.

2. SITE BACKGROUND

The Alaska Real Estate Parking Lot property consists of Lots 8A – 12, Block 26A East Addition located at the northeast corner of 4th Avenue and Gambell Street intersection in Anchorage, Alaska, as shown on Figure 1. The property is owned by Fourth Avenue and Gambell Associates LLC. The subject property was formerly occupied by a variety of businesses, including C&K Cleaners (which was a dry cleaner) from approximately 1968 through 1970, and Northern Commercial (NC) Tire Center from 1976 to 1978 which was the last occupant of the last building on the eastern portion of the site prior to being demolished in 1978. The property has since served as a parking lot.

The property includes approximately 40,600 square feet of land and the immediate vicinity is generally flat at approximately 110 feet above mean sea level. The surrounding area has a gentle slope to the north towards the Ship Creek drainage at which point a steep drop-off in elevation occurs.

Presently the site is a predominately undeveloped and unpaved area this is used for parking. A communications tower/antennae located at the south east corner of the property and owned by Alaska Communications is the only other improvement currently located on the site.

Property east, south, and west of the site is primarily retail and commercial including a restaurant, printing facility, and church. The property directly north of the site is residential with a variety of single- and multi-family residences. Third Avenue and the former Alaska Native Hospital property, which is now vacant, are located to the north beyond the residential buildings.

2.1. Investigation Summary

Extensive site investigation work has been performed at the site, beginning with a Phase I Environmental Site Assessment (ESA) that was conducted in 1993. The Phase I ESA identified the operation of a C&K Cleaners from 1968 to 1970 and a (NC) Tire Center from 1976 to 1978. C&K Cleaners appears to have been located on the western side of the property, and NC Tire Center appears to have been located on the eastern side of the property. The Phase I site reconnaissance indicated that an underground storage tank (UST) vent pipe was visible on the property. All buildings were removed from the site in 1978. The site has since served as a parking lot (EnviroAmerica, 1993).

A Phase II ESA was performed in 1997. The findings of the Phase II ESA indicated that areas of contaminated soil and groundwater were identified on the subject property. The two main areas of interest were located in the western portion of the subject property, where the former dry cleaner building was located, and in the northeastern area of the property, where the former NC Tire Facility was located. Three trenches dug near the former C&K Cleaners unearthed a log crib and four empty drums marked for use in dry cleaning. A soil sample collected from the drum area at 7 feet below ground surface (bgs) had a concentration of tetrachloroethene (PCE) of 3.2 mg/kg and one soil sample from the log crib area, collected at 12 feet bgs, contained 1.0 mg/kg of PCE. Seven hydraulic lifts, associated piping, sumps, an UST, and a log crib were also identified near the former NC Tire Center. Three soil samples collected near the log crib had concentrations of PCE, ethylbenzene, toluene, 1,2,4-trimethylbenzene, 1,3,5-trimethylbenzene, arsenic, barium, cadmium, and chromium above ADEC soil cleanup levels. Three monitoring wells (MW-1, EPM-2, and EPM-3) also were installed. Groundwater samples were collected from each well and analyzed for volatile organic compounds (VOCs), metals, and petroleum hydrocarbons. No volatile organic compounds (VOCs) were detected in EPM-2 and EPM-3. The concentration of PCE in MW-1 was 4.25 mg/L (EPMI, 1997).

Another Phase II ESA was performed in August 2004, which included excavation of six test pits, removal of five hydraulic lifts, removal of four USTs, removal of soil contaminated with diesel range organics (DRO) above the ADEC soil cleanup level, and sampling of monitoring well MW-1. The hydraulic lifts and USTs were associated with the former NC Tire Center operation. The contaminated soil came from underneath the hydraulic lifts and USTs. Concentrations of PCE above the ADEC SCL (1.73 to 4.2 mg/Kg) were detected in three of the test pits. These three test pits were located on the western side of the property near the location of the former C&K Cleaners (BGES 2004a).

Monitoring well MW-1 was sampled in October 2004. The sample was analyzed for VOC's by United States Environmental Protection Agency (EPA) method 8260. The concentration of PCE was 2.28 mg/L, which exceeds the ADEC groundwater cleanup level of 0.005 mg/L. All other compounds were less than laboratory reporting limits (BGES 2004b).

Three additional monitoring wells (MW-2, MW-3, and MW-4) were installed around the former C&K Cleaners building in March 2005. Soil samples were collected from various intervals during drilling and were analyzed for VOC's. Concentrations of PCE ranged from 2.13 mg/kg in the interval from 36 to 38 feet bgs in MW-4 to 79.5 mg/kg in the interval from 28 to 30 feet bgs in MW-2. All other compounds were less than laboratory reporting limits. PCE results for groundwater were 1.49 mg/L in MW-1, 0.0707 mg/L in MW-2, 1.79 mg/L in MW-3, and 0.372 mg/L in MW-4. All other compounds in groundwater were less than laboratory reporting limits. The conclusion was made that biodegradation of PCE was not occurring at a significant rate because of a lack of PCE daughter compounds and the oxygenated state of the aquifer (BGES 2005). However, it should be pointed out that dissolved oxygen (DO) was measured at ground surface in purge water obtained by the use of a bailer, which generally does not provide a representative measurement for DO.

Five shallow soil borings (A, C, D, E, and F) were drilled to depth of 15 feet bgs and three monitoring wells (MW-5, MW-6, and MW-7) were installed in an assessment performed in 2007. Soil samples were collected from two or three intervals in all eight borings. The levels of PCE in surface soil samples (0 to 2 feet bgs) ranged from 1.27 to 13.2 mg/kg and PCE ranged from 0.865 to 821 mg/kg in the subsurface (over 2 feet bgs) soil samples. Concentrations of PCE exceeded the ADEC cleanup values for migration to groundwater per 18 AAC 75.341 of 0.024 mg/kg in all soil samples. Trichloroethene (TCE) was also detected above the ADEC cleanup values for migration to groundwater per 18 AAC 75.341 of 0.020 mg/kg in the two soil samples collected from boring D at concentrations of 0.0439 and 0.0352 mg/kg. Concentrations of PCE in groundwater exceeded the cleanup level of 0.005 mg/L in all three wells: 0.523 mg/L in MW-5, 0.822 mg/L in MW-6, and 0.0051 mg/L in MW-7 (BGES 2007).

ADEC assumed the lead role on the project in 2008 following Fourth Avenue and Gambell Associates LLC indication that they were unable to fund any additional investigations. OASIS Environmental performed a site characterization in July 2008. The site characterization included installing and sampling six soil borings (SB-1, SB-2, SB-3, SB-4, SB-5, and SB-6), sampling monitoring wells MW-5 and MW-6, and sampling two temporary wells (SB-1 and SB-2). Analytical results for soil borings SB-2, SB-3, SB-4, SB-5, and SB-6 indicate an area of PCE-impacted soil that is located north and northeast of the former C&K Cleaners. Contamination is present at ground surface in the areas of SB-2, SB-3, and SB-4, but the significant mass of contamination occurs in a gravelly sand profile that begins around 15 feet bgs and extends to approximately 35 feet bgs. The levels of PCE in soil ranged from 0.26 to 54 mg/kg. Analytical results from groundwater samples collected at the monitoring and temporary wells during this site characterization demonstrate that the PCE exceeds the ADEC cleanup level underneath the entire area of the former C&K Cleaners. The plume appears to extend northeastward, which is the reported direction of local groundwater flow. Based on the elevated PCE concentration in MW-2 (0.115 mg/L) and MW-6 (1.60 mg/L), the plume could possibly extend west of Gambell Street and north of 3rd Avenue, respectively. The absence of PCE or other significant concentrations of VOC's in soil samples and groundwater from the temporary up-gradient well SB-1 indicates that an upgradient source is not believed to be contributing to contamination at the subject site (OASIS 2008).

In 2008, the Environmental Protection Agency (EPA) hired CH2M HILL and Ecology and Environment (E&E) to evaluate potential upgradient sources of contamination that may be impacting Alaska Railroad Corporation's (ARRCs) Anchorage Terminal Reserve Groundwater Area of Interest GW 2/3 located on the south side of Ship Creek along Ship Creek Avenue and west of Ingra Street. The EPA requested a supplemental groundwater investigation that included installation and sampling of 15 temporary well points and sampling of 13 existing monitoring wells for VOCs, GRO, and DRO. Eight of the temporary well points were located just north of the Alaska Real Estate Parking Lot between 3rd and 1st Avenues (Blocks 35 and 36 East Addition Subdivision) on vacant land where the Alaska Native Hospital was formerly located. PCE was detected in three of these temporary wells (WP8, WP11, and WP12) at concentrations of 0.14 to 0.62 mg/L. PCE was also detected at a concentration of 0.023 mg/L in an existing monitoring well (MW-28) located at the base of the bluff and downgradient from the three temporary wells. Interestingly MW-28 also containted substantial concentrations of PCE breakdown products: including cis-DCE (0.18 mg/L) and vinyl chloride (0.022 mg/L).

Only trace or non-dectable levels of breakdown products cis-DCE and vinyl chloride were detected in the plume at the top of the bluff, which suggests that PCE does not significantly biodegrade until the plume is comingled with the petroleum hydrocarbon plume at the base of the bluff (CH2M Hill and E&E, 2008).

OASIS performed additional site characterization in March 2009 and May 2009 with the inclusion of vapor intrusion assessments at four residential buildings located on Lots 1-6, Block 26A East Addition just north of the Alaska Real Estate Parking Lot site. The assessments included the collection of soil gas samples, outdoor air samples outside each building, and the collection of either indoor air or crawl space air samples. Analytical results from the two assessments indicated that PCE was present in soil gas at concentrations exceeding ADEC target soil gas levels at all four residences for both sampling events. In addition, indoor air or crawl space analytical results showed that PCE also was present above ADEC indoor air target levels at all four residences for both sample events, except for the south duplex in June 2009. These findings indicated that PCE was present in the residences above risk-based screening levels, likely as a result of vapor intrusion (OASIS 2009).

Additional vapor intrusion and soil gas assessment activities were performed in February and May 2010. The assessment included indoor or crawl space air samples at the four residential buildings noted above. The results indicated that PCE concentrations exceeded ADEC target levels for both soil gas and indoor air, much the same as the results from the 2009 assessment. A passive soil gas survey was also performed for the four-block area between 3rd and 4th Avenues and between Gambell and Ingra Streets. The passive soil gas results showed that elevated PCE concentrations occur around the former C&K Cleaners and extend to the four residences. Elevated concentrations of PCE were also detected adjacent to the PIP Printing and First Native Baptist Church buildings, located one block east of the site (OASIS 2010).

In 2011, OASIS Environmental evaluated the extent of contamination east of the subject property (i.e., between 4th Avenue and 3rd Avenue and between Hyder and Ingra Streets). Four soil borings were advanced and converted to monitoring wells and ten soil gas probes were installed on Block 26B, East Addition Subdivision. Soil, groundwater, and soil gas samples were collected and analyzed for VOCs. Analytical results show that soil, groundwater, and soil gas samples were below ADEC cleanup levels or target criteria for PCE, suggesting that PCE contamination has not migrated east of the Block 26A East Addition Subdivision where the subject property is located (OASIS, 2011).

In 2012, the EPA hired E&E to further characterize the source and extent of contamination previously observed at the C&K Cleaners and surrounding locations. E&E advanced 13 soil borings that were sampled at five foot intervals and of which 12 were completed as monitoring wells. Additionally 31 surface soil, 10 soil gas, 12 indoor and 8 outdoor air, and 10 sediment samples were collected and analyzed for VOCs. A brief summary of the investigation work performed at the site is provided below; a detailed discussion of the work can be found in E&E (2013).

- Soil samples from several boreholes (BH01, BH02, BH03, BH05, BH07, BH08, and BH09) located near the former C&K Cleaners reported elevated concentration of PCE at varying depths down to 50 feet bgs (maximum depth sampled). The 45-50 feet bgs soil sample from BH11 (located on the former Native Hospital site north of 3rd Avenue) contained 0.15 mg/Kg of PCE.
- PCE was reported in groundwater above the MCL of 0.005 mg/L in eight of the groundwater monitoring wells sampled with PCE concentrations ranging from 0.0078 to 8.5 mg/L. PCE was not observed in the only groundwater sample (BH12) taken north of 3rd Avenue, but this sample had an elevated reporting limit. No groundwater sample was collected at BH11 but the soil contamination and previous groundwater monitoring results show that PCE is present at this location.
- Four of the indoor air samples were above ADEC indoor air target level of 4.1 $\mu g/M^3$ in the two duplex buildings located on Lot 2, Block 26A, East Addition Subdivision.
- Two of the soil samples located near the former C&K Cleaners had PCE concentrations that exceed the ADEC soil cleanup value of 0.024 mg/kg for migration to groundwater per 18 AAC 75.341.
- Ten sediment samples collected from along Ship Creek were all below the reporting limit for PCE.

2.2. Soil and Groundwater Contamination Summary

PCE impacted soil above the ADEC 18 AAC 75.341 Table B1 cleanup level for migration to groundwater has been documented in an area surrounding the former C&K Cleaners and extending northerly onto residential properties in the soils deeper than 10 feet bgs. The vertical soil contaminant levels are very variable with PCE concentrations falling below soil cleanup levels only to reappear again in deeper soil samples. The primary zone of soil contamination falls in an area of approximately 28,000 square feet around the former C&K Cleaners. The vertical extent of PCE contamination is known to extend to at least a depth of 50 feet bgs, but the total extent is unknown. E&E estimated that the total volume of contaminated subsurface soil associated with contaminant sources from the Alaska Real Estate Parking Lot site to be approximately 22,700 cubic yards (E&E, 2013).

Groundwater impact by PCE above the ADEC 18 AAC 75.345 Table C cleanup level has been documented in an area surrounding the former C&K Cleaners (Figure 5). The PCE plume extends northeasterly across 3rd Avenue and down the bluff towards the Alaska Railroad Corporation's Anchorage Terminal Reserve and Ship Creek. The groundwater plume is estimated to cover approximately 370,000 square feet or approximately 8 acres. Note that few groundwater monitoring wells have been installed along the downgradient portion of the PCE plume, and that other potential sources of chlorinated solvent contamination are present along the Ship Creek area, so there is some degree of uncertainty in the plume size especially along the leading edge.

2.3. Geologic Setting

2.3.1. Regional Surficial Geology

The Alaska Real Estate Parking Lot site is located on the southern bluff of Ship Creek. The site is located approximately 1,700 feet south of Ship Creek on a bluff that rises approximately 40 to 50 feet above Ship Creek.

The City of Anchorage is located on a moderately broad lowland bounded on the east by the Chugach Mountains, on the west by Cook Inlet, and by Knik Arm and Turnagain Arm of Cook Inlet to the north and south (respectively). Unconsolidated deposits in this area include glacial, alluvial, colluvial, and lacustrine deposits. The unconsolidated deposits were placed during multiple glacial and non-glacial geologic events, resulting in a complex, vertically discontinuous stratigraphy, measuring from 650 feet thick near Anchorage to only several feet thick along the Chugach Mountains.

The surficial geological conditions primarily consist of quaternary glacial outwash deposits comprised of gravel, sand, silt, and clay. The deposits vary in thickness depending on location but are approximately 50 feet thick along the top of the bluffs adjacent to Ship Creek. These deposits are interfingered with thin silt and fine sand lenses. The entire area is underlain with a layer of poorly permeable silty-clay, known locally as the Bootlegger Cove Formation. The Bootlegger Cove Formation was deposited over older sand, gravel, and glaciofluvial silt which were then subjected to a period of erosion before deposition of the Bootlegger Cove Formation. The cohesive facies of this formation have been referred to as the Bootlegger Cove clay or the "blue clay". The Bootlegger Cove Formation ranges in thickness from zero up to about 300 feet and averages about 100 to 150 feet.

2.3.2. Local Surficial Geology

The site is located on a gravel parking lot overlying glacial outwash deposits along Ship Creek. Test pit and boring log information for this area indicated that the shallow subsurface soils consist of sandy gravels or gravelly sands in accordance with the Unified Soil Classification System (USCS) to depths of approximately 50 feet where the Bootlegger Cove Formation was encountered. The sandy gravel and gravelly sand is a gray-brown and poorly sorted. Several 1-inch to 3-inch coal layers were observed between 15 and 40 feet bgs in several of the borings. A gray-brown, well sorted sand, containing no gravel was observed from approximately 30 to 45 feet bgs in all borings across the site. Thin clay layers (0.1 to 1 feet thick) were present in numerous boreholes starting between 44 and 48 feet bgs. The clay is very dense, plastic, and varies in color from yellowish-gray to brick red.

Figure 5 displays a plan view of monitoring well and soil boring locations and the locations of cross-sections A-A', B-B', and C-C'. The cross-sections, presented in Figures 6, 7, and 8, illustrate the subsurface geology (i.e., coal seam layers and the underlying clay base layer) and contamination across the site.

No reported grain size classification tests have been performed on any of the subsurface soil samples from the site.

2.4. Hydrogeology

2.4.1. Regional Hydrogeology

Two primary groundwater aquifers are known to exist in this area. The upper aquifer is unconfined and is mainly a locally continuous sheet of outwash sediments varying from 10 feet to 50 feet in thickness. The lower aquifer is confined and consists of interfingered sands, gravels, and tills that thin and merge with the upper aquifer materials near the Chugach mountain front to the east of Anchorage. The intervening confining unit is a continuous layer of clay and silt known locally as the Bootlegger Cove Formation. This unit grades eastward to tills and till-like deposits and pinches out near the mountain front. The Bootlegger Cove formation was inferred to between approximately 80 and 144 feet thick within the cadastral boundaries of the Alaska Real Estate Parking Lot property. Regionally groundwater in both the confined and unconfined aquifer systems flows in a generally westward direction from the Chugach Mountains to Cook Inlet.

The sand and gravel of the unconfined and confined aquifers are exceptionally permeable. Recharge studies were conducted by temporarily diverting the flow of Ship Creek into storage basins on Fort Richardson. A permeability of 68.6 m/day (225 ft/day) was calculated from this study (Anderson, 1977).

The mean annual precipitation for Anchorage, Alaska, as measured at Merrill Air Field from November 1997 to December 2008, is 14.78 inches (WRCC, 2013).

2.4.2. Groundwater Elevation and Horizontal Groundwater Flow

The upper unconfined aquifer appears to flow generally toward the north to northeast and then switches to a more northwesterly direction near the base of the bluff until it flows into Ship Creek (E&E, 2013).

Based on the static groundwater measurements taken during the 2008 Area GW 2/3 Supplemental Groundwater Investigation (CH2M Hill and E&E, 2008), the general local groundwater flow direction is toward the north (Figure 2). Local variations in the groundwater flow directions are noted with a more northwesterly direction on western portion of the former Native Hospital property and a more northeasterly direction on the eastern portion of the former Native Hospital property. The groundwater surface elevation in this area roughly mimics the ground surface elevation. A groundwater gradient of approximately 4 feet per 100 feet is present between the site and Ship Creek (i.e., 10 feet of horizontal distance equates to a 0.4 foot change in groundwater elevation). The groundwater gradient is slightly less in the immediate vicinity of the site with a gradient of approximately 1.25 feet per 100 feet (i.e., 10 feet of horizontal distance equates to a 0.125 foot change in groundwater elevation).

2.4.3. Vertical Groundwater Flow

Vertical groundwater gradient has not been evaluated at this site but is expected to be downward in the unconsolidated materials above the Bootlegger Cove Formation.

2.4.4. Hydraulic Conductivity and Seepage Velocity

Based on the grain size classification tests shown in**Error! Reference source not found.**, physical aquifer parameters were obtained from literature and are summarized below in Table 2-1.

TABLE 2-1: GROUNDWATER FLOW PARAMETER SUMMARY

		Hyd Cond (K) [cm/s] [a,b]			Total Porosity (n) [a]	Eff. Porosity (n) [a]	Dry Bulk Density (lbs/ft^3) [b]
Description	**Soil Type** [c]	**High**	**Low**	**Geo. Mean**	**Average**	**Average**	**Average**
Fill (vadose)	Sandy Gravel (GW)	1	0.03	0.17	0.32	0.28	130
Silt (saturated & vadose)	Slightly Sandy Silt (ML)	1.0E-03	1.0E-07	1.0E-05	0.48	0.16	108
Native Sand Below Silt (saturated)	Gravelly Sand (SP)	1	0.003	0.055	0.39	0.28	110

a *Natural Attenuation of Fuels and Chlorinated solvents in the Subsurface*, Wiedemeier, 1999.
b Freeze & Cherry 1979
c *Civil Engineering Reference Manual, Sixth Edition*, Lindeburg, 1992.
d *S&W 2010 Grain Size Classification Tests*

Seepage velocities were calculated for the gravelly sand layer based on the average hydraulic conductivity, porosity, and the range of measured hydraulic gradients. Theoretical annual travel distances were calculated from the seepage velocities reflecting the seasonally-variable groundwater gradients and are presented below in **Error! Reference source not found.**. Note that **Error! Reference source not found.** presents only travel distances based on average hydraulic conductivity and porosity values for sand and does not consider travel through the silt or any heterogeneitites.

The travel speed of dissolved-phase contamination is slower than the travel speed of the water, due to sorption processes slowing the contaminant front. This phenomenon is generally referred to as “retardation” and may be quantified by a retardation coefficient that expresses how much slower a contaminant moves compared to the water. The retardation coefficient for PCE at the Alaska Real Estate Parking Lot site was calculated by the following equation.

$$R = 1 + \frac{Kd * \rho b}{\varphi}$$

Where: R is the retardation coefficient = 9.5, based on parameter values below;

ρb is the bulk density (assume 1.7 g/cm^3);

K_d is the sorption coefficient = K_{oc} [organic carbon coefficient of contaminant]*foc [fraction of organic carbon in the soil]) (272 L/kg*0.0055=1.496; and

φ is the porosity (0.3).

A retardation factor of 9.5 indicates that PCE travel will be retarded by a factor of almost 10 as compared to the groundwater velocity. This is a high retardation factor, reflecting PCE's high affinity for sorption onto soil.

2.4.5. Coal and TOC

As discussed previously, there are thin layers of coal underlying the Alaska Real Estate Parking Lot site. The coal seams vary depending on location, often consisting of two or more coal seams at varying depths ranging from approximately 15 to 45 feet bgs. The thickness of the coal seams is also variable but often in the range of 1 to 4 inches or less.

Three figures were prepared to assist in interpreting the coal seams. Figure 5 presents the locations of three cross-sections, A-A', B-B', and C-C' (Figures 6, 7, and 8, respectively). Each of these figures is discussed below.

Cross-Section A-A': Cross-Section A-A' originates at the southwestern corner of the site and extends in a northeast direction along the southeastern corner of the former C&K Cleaners building. Cross-Section A-A' starts at MW-7 and extends to BH-03 where it intersects cross-section C-C'.

Multiple coal lenses were observed in each of the borings shown on Cross-Section A-A' but very few appear to be correlated between multiple boreholes. No obvious correlation is noticeable between PCE concentrations and the occurrence of coal lenses.

The area of highest groundwater contamination concentrations extends between MW-4 (372 μg/L) and temporary well BH-09 (360 μg/L) both of which are located near the former C&K Dry Cleaners building. The furthest out monitoring points (MW-7 and BH-03) have groundwater PCE concentrations that are just above the cleanup level of 5 μg/L.

Cross-Section B-B': Cross-Section B-B' also originates at the southwestern corner of the site and extends in a north to northeast direction across the site and into the residential properties north of the site where it ends at SB-6. It runs parallel to the western side of the C&K building before turning and crossing downgradient of the northern end of the building and beyond.

Multiple coal lenses were observed in each of the borings shown on Cross-Section B-B' but only a few appear to be correlated between multiple boreholes. It should also be noted that the coal lens at approximately 28 feet bgs between BH-08 and BH-05/MW-2 coincides with very high levels of PCE contamination in the soil samples from these borings. **This suggests that the coal lens is acting as absorbent material for the PCE contamination.**

Relative to the groundwater table, the well screen sections for MW-5 and MW-6 appear to be completed above the 2008 (E&E, 2008) measured groundwater elevations. Potential impacts on the groundwater results from these monitoring wells should be considered.

The area of highest groundwater contamination concentrations extends between BH-05/ MW-2 (1,600 μg/L) and MW-6 (1,600 μg/L) both of which are located north and downgradient of the former C&K Dry Cleaners building.

Cross-Section C-C': Cross-Section C-C' originates at the western end of the site and extends in an easterly direction along the northern end of the former C&K Cleaners building. Cross-Section C-C' starts at MW-2 and extends to BH-03 where it intersects cross-section A-A'.

Multiple coal lenses were observed in each of the borings shown on Cross-Section C-C' but only one appears to be correlated between multiple boreholes. This is the same coal lens as shown on Cross-Section B-B' that coincides with elevated concentrations of PCE in the borehole soil samples.

The area of highest groundwater contamination concentrations extends between temporary well BH-05 (1,600 μg/L), MW-1 (1,490 μg/L), and temporary well BH-07 (350 μg/L) which are located just north of the former C&K Dry Cleaners building.

TOC Data: During the 2007 site investigation (BGES, 2007) eight soil samples were analyzed for total organic carbon (TOC). The TOC concentrations ranged from not detected (< 1,000 mg/Kg) in two samples to 519,000 mg/Kg in a sample at 32.5 to 34.5 ft bgs from MW-7. Presumably this TOC concentration has been impacted by the coal seam layers that are present above and below the sample location.

Assuming that the non-detect TOC concentrations are equal to the detection limit and excluding the highest TOC concentration the average TOC concentration from the remaining seven samples is 5,500 mg/Kg or fraction of organic carbon (foc) of 0.0055.

2.5. Estimate of Soil and Groundwater Contamination

The extent of PCE contaminated soil is shown on Figure X. The groundwater PCE plume is shown in Figure 3. The extent of PCE soil contamination and groundwater plume are discussed in detail in the following subsections.

2.5.1. PCE Contaminated Soil

2.5.2. PCE Groundwater Contaminant Plume

The Alaska Real Estate Parking Lot PCE contaminant plume is estimated at 370,000 square feet or approximately 8 acres (Figure 3). The PCE plume extends northeasterly across 3rd Avenue and the former Aand down the bluff towards the Alaska Railroad

Corporation's Anchorage Terminal Reserve and Ship Creek. The plume boundaries have been well-delineated to the south by temporary wells BK-01GW and SB-1, east by monitoring wells MW-8 through MW-11, and west by BH04SB and WP-10. The contaminant plume is known to extend over 1,300 feet to the north (MW-28) and possibly beyond. Note that few groundwater monitoring wells have been installed along the downgradient portion of the PCE plume, and that other potential sources of chlorinated solvent contamination are present along the Ship Creek area, so there is some degree of uncertainty in the plume size especially along the leading edge. Ten sediment samples were collected along Ship Creek during July 2012 to determine if contamination from the site is impacting Ship Creek. No VOCs were detected in any of the sediment samples collected from Ship Creek (E&E, 2013).

The groundwater contaminant plume is illustrated in Cross Sections A-A', B-B', and C-C' (Figure 6, 7, and 8). As shown in these figures and discussed in the previous section, a vadose zone of approximately 40 to 45 feet overlies the groundwater saturated interval. The thickness of this saturated interval is poorly defined as most boreholes did not definitively encounter the underlying Bootlegger Cove clay formation. Clay was encountered from 47.5 to 50 feet bgs in BH-03, 46 to 48 feet bgs in BH-04, 45.5 to 50 feet bgs in BH-06, and 45 to 50 feet bgs in BH-08 (E&E, 2013). However other boreholes passed through 1 to 2 feet thick clay layer and then encountered more sandy material (e.g. BH-05, BH-07, and BH-09).

2.5.3. Data Gap Summary

2.6. Conceptual Site Model

A conceptual site model (CSM) was prepared for the Alaska Real Estate Parking Lot site using the ADEC CSM scoping form and the human health conceptual site model graphic form. The following exposure pathways are potentially complete:

- **Ingestion of groundwater**: All groundwater in Alaska is considered a potential drinking water source unless determined otherwise using the criteria presented in 18 AAC 75.350. No groundwater determination has been completed for this site under 18 AAC 75.350. There are two drinking water wells near the site (high school drinking water well and middle school drinking water well). Contamination has not been detected in either drinking water well, and sentry monitoring wells installed between the groundwater contamination and the drinking water wells have also not detected any contamination.

Ingestion of groundwater is a potentially complete pathway for the following receptors:

  - Current and Future residents, commercial or industrial workers, site visitors/recreational users, and construction workers.

- **Inhalation of volatile compounds in tap water (showering):** TCE is a volatile compound. If a contaminated water supply were used for tap water, the inhalation of volatile compounds would be a complete exposure pathway for the following receptors:
  - Current and Future residents, commercial or industrial workers, site visitors/recreational users, and construction workers.
- **Inhalation of volatile compounds in indoor air:** Indoor air inhalation is considered a potentially complete pathway for TCE in groundwater and for TCE in the vadose zone. As discussed previously, air purifying filters and an SSD are in place to mitigate the vapor intrusion pathway for TCE in the Middle School building. The contribution of volatilizing TCE from groundwater to the vapor intrusion pathway is unknown, but ADEC CSM guidance (ADEC, 2005) states that the vapor intrusion pathway should be considered complete if nonpetroleum contamination in soil or groundwater is found within 100 vertical or horizontal feet of a building.

Several of the pathways shown to be potentially complete in the CSM for the entire site are not considered complete when considering only the groundwater TCE plumes, as explained below.

- Outdoor air inhalation is not considered a potentially complete pathway for TCE in groundwater due to the groundwater depth. ADEC (2005) states that the outdoor inhalation pathway must be considered for contamination detected between ground surface and 15 feet bgs.
- Dermal adsorption is not considered a potentially complete pathway for TCE and DCE (ADEC, 2005).
- Surface water exposure is not considered a potentially complete pathway. The hydrogeological evaluation showed a very low groundwater gradient at the site with variable flow direction. There is no evidence that the groundwater contamination has migrated off-site towards Aniak Slough or the Kuskokwim River, nor do the data suggest that future off-site migration is a concern.

3. REMEDIAL ACTION OBJECTIVES

The overall objectives of environmental site restoration are to ensure that conditions at the site are protective of human health and the environment and to comply with relevant state and federal regulations. The primary goal of remedial action at the Alaska Real Estate Parking Lot site are the following:

- Reduce current human health exposure risk below the ADEC threshold cancer risk level of 1:100,000 and threshold non-cancer hazard index of 1.
- Protect the Ship Creek surface water and sediments from migrating groundwater contamination. Note that to date, site characterization data are lacking to fully define potential impacts to Ship Creek. Additional site characterization activities are recommended in the future to address these potential impacts.

The specific remedial action objectives (RAOs) proposed to reduce human health exposure risk are listed below. The RAOs are listed in order of decreasing immediate importance. RAO 1 is the most immediately important objective, because indoor air sampling has shown elevated concentrations of PCE in the indoor air and crawl space of homes located adjacent to the Alaska Real Estate Parking Lot site.

1. **Indoor Air Pathway**: Reduce indoor air concentrations of PCE (and if necessary also TCE, DCE, and VC) to meet the ADEC target cleanup levels protective of human health (ADEC, 2012) (Table 3-1).
2. **Incidential soil ingestion and migration to groundwater pathways**: Reduce concentrations of PCE, TCE, DCE, and VC in soil to meet the ADEC Table B1 human health risk-based cleanup levels (ADEC, 2009) (Table 3-2).
3. Groundwater ingestion pathway: Over time, reduce concentrations of PCE, TCE, DCE, and VC in groundwater to meet the ADEC Table C cleanup levels (ADEC, 20xx) (Table 3-3).
4. Sediment/surface water pathways: If necessary to protect Ship Creek, reduce concentrations of PCE, TCE, DCE, and VC in groundwater migrating to Ship Creek.

A secondary goal of remedial action is to reduce contaminant levels or migration pathways in the source area in order to reduce the mass of contamination in the vapor phase (i.e., vapor intrusion pathway) and in the groundwater.

TABLE 3-1: MAXIMUM INDOOR AIR CONCENTRATIONS AND ADEC CLEANUP LEVELS

Contaminant	Maximum Concentration ($\mu g/m^3$)	Sample Type	Location of Maximum Concentration (Sample Month)	ADEC Residendial Target Levels for Indoor Air ($\mu g/m^3$)*
2010 Sampling				
PCE	51	Indoor Air	IA-2 (February)	42
PCE	110	Crawl Space Air	CS-1 (May)	42
2009 Sampling				
PCE	58	Indoor Air	IA-2 (March)	42
PCE	170	Crawl Space Air	CS-1 (March)	42

Notes:
$\mu g/m^3$ = Micrograms per cubic meter
PCE = tetrachloroethene
*Residential target levels are provided in *Vapor Intrusion Guidance for Contaminated Sites* (ADEC, October 2012).

TABLE 3-2: MAXIMUM SOIL CONCENTRATIONS AND ADEC CLEANUP LEVELS

Contaminant	Maximum Concentration (µg/kg)	Location of Highest Concentrations (Sample Depth/Year)	ADEC Levels for Migration to Groundwater (µg/kg)	ADEC Table B1 Cleanup Level Outdoor Inhalation (µg/kg)
2012 Sampling				
PCE	56,000	BH-08 (30)	24	10,000
PCE	3,400	BH-05 (30)	24	
PCE	3,400	BH-05 (50)	24	
1997 - 2008 Sampling				
PCE	79,500	MW-2 (30/2005)	24	
PCE	54,000	SB-3 (29/2008)	24	
PCE	821,000	D (14/2007)	24	
PCE	45,000	SB-2 (25/2008)	24	

Notes:
µg/kg = Micrograms per kilogram
ND = Not detected

TABLE 3-3: MAXIMUM GROUNDWATER CONCENTRATIONS AND ADEC CLEANUP LEVELS

Contaminant	Maximum Concentration (µg/L)	Location of Maximum Concentration (Sample Month)	ADEC Residendial Target Levels for Groundwater (µg/L)*	ADEC Table C Cleanup Level (µg/L)**
2011 Sampling				
TCE	77	MW-5 (May)	0.55	5
cDCE	3.1	MW-7 (October)	220	70
Vinyl chloride	ND	--	0.71	2
2009 Sampling				
TCE	47.5	MW-7 (August)	0.55	5
cDCE	2.81	MW-7 (August)-dup	220	70
Vinyl chloride	ND	--	0.71	2
2008 Sampling				
TCE	187	TWB-12S (June)-dup	0.55	5
cDCE	18.8	TWB-13S (June)	220	70
Vinyl chloride	ND	--	0.71	2

Notes:
µg/L = Micrograms per liter
ND = Not detected
TCE = trichloroethene
cDCE = cis-1,2-dichloroethene
Vinyl chloride not detected above laboratory reporting limits in groundwater samples.
*Residential target levels are provided in *Draft Vapor Intrusion Guidance for Contaminated Sites* (ADEC, 2009).
**Cleanup levels are provided in Table C of the Alaska Contaminated Site Regulations (18 AAC 75.345).

4. DESCRIPTION OF ALTERNATIVES

Five remedial alternatives were evaluated to address vadose-zone soil contamination, and five remedial technologies that are potentially appropriate for treating dissolved PCE contamination were evaluated to address groundwater contamination at the Alaska Real Estate Parking Lot site. The primary focus of this feasibility study is on the soil alternatives, which are necessary to reach the primary goal of reducing current exposure to ADEC risk threshold levels.

4.1. Remedial Alternatives

Five remedial alternatives were developed and evaluated to address contamination of the soil and coal layers and five remedial alternatives were developed and evaluated to address the groundwater contamination at the Alaska Real Estate Parking Lot. The alternatives are listed below and discussed in the following sections.

S-1. No Action;
S-2. Soil Vapor Extraction (SVE);
S-3. In-Situ Chemical Oxidation (ISCO);
S-4. In-Situ Thermal Remediation (ISTR); and
S-5. Soil Excavation and Disposal.

GW-1. No Action;
GW-2. MNA/Long-Term Monitoring (LTM);
GW-3. In-Situ Chemical Oxidation (ISCO);
GW-4. Enhanced Bioremediation Reductive Dechlorination (ERD); and
GW-5. Permeable Reactive Barrier (Iron Wall?).

4.2. General Assumptions for all Alternatives (except No Action)

4.2.1. Vapor Intrusion Mitigation

The primary current human health risk at this site is indoor air inhalation due to vapor intrusion into the homes located adjacent to the Alaska Real Estate Parking Lot site. Therefore, operation of a vapor intrusion mitigation system or alternative SVE system is assumed for protection of human health until soil and groundwater RAOs are met[1] or the vapor intrusion risk has been mitigated. SVE system operation costs include OM&M

[1] The relative contribution to the vapor intrusion pathway of dissolved-phase PCE from the saturated zone versus PCE from soil gas in the vadose zone has not been established. If vadose zone soil remediation decreases soil gas and indoor air PCE concentrations below ADEC target levels, then it is possible that SVE could be discontinued before groundwater RAOs are met.

activities on a quarterly basis for five years, annual electricity costs, and blower replacement every five years for the duration of the remedy.

4.2.2. Groundwater Monitoring

Groundwater monitoring is an important component of all of the alternatives. The following groundwater monitoring scope was used for each alternative for cost-estimating purposes, although the actual monitoring scope may deviate somewhat from the details provided below.

- Installation of approximately 5 new monitoring wells;
- Quarterly groundwater monitoring of 15 wells for one year;
- Semi-annual groundwater monitoring of 15 wells for three years;
- Annual groundwater monitoring of 15 wells for 16 years; and
- Groundwater monitoring of 15 wells every 5 years until remedy completion.
- Confirmation sampling to verify that RAOs have been reached will be provided by the annual groundwater monitoring.

4.2.3. Institutional Controls

All of the groundwater alternatives will have an IC component to protect human health until RAOs are met. In general, ICs include engineering controls, such as fences, and document controls, such as deed restrictions, to restrict site activities that could pose a potential threat to human health. The ICs anticipated for the Alaska Real Estate Parking Lot site include restricting the installation of drinking water wells in the vicinity of the groundwater plume.

The formality and duration of ICs will vary by alternative, depending on its remedial timeframe. The costs for establishing ICs are not specifically included in the cost analysis but would be included in the contingencies.

4.2.4. Cost Estimating

Costs for each alternative were prepared consistent with the *FS Cost Estimating Guidance* (EPA, 2000). The detailed cost estimates include capital costs, OM&M costs, contingencies, and present value analysis to allow direct comparison of alternatives with different remedial timeframes. Present value costs were calculated using a 7 percent discount rate, as recommended for non-federal-government-funded projects in the EPA guidance. Although detailed cost estimates were prepared for each alternative, the cost estimate accuracy is considered to be more similar to a screening-level analysis than a detailed analysis, due to the significant data gaps remaining with respect to the nature and extent of contamination at the site. Therefore, the costs are presented in a range of -50% to +100%, which is the high end of the uncertainty range shown in Exhibit 2-3 of the FS guidance.

4.2.5. Data Gaps

As discussed previously, there are still some significant data gaps to be addressed before implementing soil and groundwater remediation at this site. The total depth of contamination is unknown across much of the site. Hydrogeological and geotechnical data are very limited with regards to permeability or hydraulic conductivity. The nature and extent of contamination in site soil and groundwater has been incompletely characterized. Only limited total organic carbon (TOC) data have been collected from the site and only one appears to have been collection from the coal layers to assess adsorption and contaminant retardation parameters.

MNA parameter monitoring should also be performed to characterize geochemical conditions for the site. Microbial community testing for dehalococcoides organisms and possibly other organisms and functional genes of interest should also be performed. Use of Bio-Trap® in-situ microcosms may be a cost-effective technique to assess the MNA potential, native microbiological community, and expected performance of substrate amendment. Additional characterization and a pilot test (or tests) of the most promising alternative(s) should be performed before implementing a full-scale cleanup and are recommended before final remedy selection.

4.3. Soil Alternatives

The soil alternatives considered in the FS are listed in Section 4.1 and discussed in the following sections. The cost estimates for each alternative are provided in Appendix B.

4.3.1. S-1: No Action

The No Action Alternative is used as a baseline reflecting current conditions without remediation. This alternative is used for comparison with each of the other alternatives.

4.3.2. S-2: Soil Vapor Extraction (SVE)

In Alternative S-2, the vadose-zone soil contaminated by PCE, TCE, or DCE above the ADEC Method Two cleanup level protective of the MTG pathway (i.e., most restrictive Method Two cleanup level) will be treated by SVE. Vapor intrusion risk will also be addressed by the SVE system removing vapors from shallow soils adjacent to existing homes. The SVE treatment area is shown in Figure X; it encompasses approximately xxx square feet of surface area.

An SVE system would be installed to treat vadose-zone contamination by PCE, TCE, and DCE. SVE is an in situ vadose-zone soil remediation technology in which a vacuum is applied to the soil to remove volatile and some semivolatile contaminants from the soil. The vacuum is typically applied through SVE wells (vertical extraction vents) or trenches (horizontal extraction vents) placed near the source of the soil contamination. In response to the vacuum, volatile contaminant vapors are drawn toward the extraction wells. In areas of high groundwater levels, water table depression pumps may be required to offset the effect of upwelling induced by the vacuum. The increased air flow through the subsurface can also stimulate biodegradation of contaminants that biodegrade aerobically. However, in the case of chlorinated solvents (such as PCE and TCE) that biodegrade anaerobically, the increased airflow is detrimental to biodegradation. The gas leaving the soil may be treated to recover or destroy the contaminants, depending on local and state air discharge regulations.

Assumptions: The assumptions used in costing the SVE system for the Alaska Real Estate Parking Lot site are listed as follows:

- Twenty-five SVE wells installed to a depth of 30 feet bgs.
- Two 15 HP blowers.
- Twelve VMPs to monitor performance of the SVE system.
- Heat tracing for year-round system operation.

The SVE wells would be installed in rows between the site and existing residential buildings to mitigate vapor transport into the buildings while treating the soil. An approximately 20-foot radius of influence was used along with the desired configuration of wells along the sides of the buildings to determine the number of wells that will be required.

The SVE system would extract VOCs from the vadose zone and emit the contaminants to the atmosphere. It was assumed that treatment of extracted vapors would not be required, because the system would emit contaminants into the atmosphere at concentrations below human health thresholds in the breathing zone and below emission levels that would result in the exhaust stack being qualified as a major source of hazardous air pollutants.

An approximately 50,000 square foot asphalt cap will be placed over the property (parking lot) and adjacent alleyway to the north. The asphalt cap will provide protection from direct exposure to shallow soil contamination in the short-term and improve the radius of influence for the SVE system.

The cost estimate assumes a 10-year operation of the SVE system. O&M activities for the first three years will include monthly inspections plus response to system upset and quarterly emissions and indoor air sampling for VOCs. O&M activities for years 3–10 include quarterly inspections plus response to system upset and annual emissions and indoor air sampling for VOCs. Electrical costs for system operation are required for years 1–10.

4.3.3. S-3: In-Situ Chemical Oxidation (ISCO)

In Alternative S-3, the vadose-zone soil contaminated by PCE, TCE, or DCE above the ADEC Method Two cleanup level protective of the MTG pathway (i.e., most restrictive Method Two cleanup level) will be treated by chemical oxidation. Vapor intrusion risk will also be addressed by the SVE system removing vapors from shallow soils adjacent to existing homes. The chemical oxidation treatment area is shown in Figure 5, along with the vapor intrusion mitigation (SVE) area.

In situ chemical oxidation (ISCO) is a rapidly growing remedial technology that involves the introduction of a chemical oxidant into the subsurface to transform groundwater or soil contamination into innocuous substances such as carbon dioxide and water. Several different forms of oxidants have been used for ISCO, including permanganate (MnO4-), Fenton's hydrogen peroxide (H_2O_2) and ferrous iron (Fe^{+2})) or catalyzed hydrogen peroxide (CHP), ozone (O^3), and persulfate ($S_2O_8^{2-}$). In addition, there are proprietary compounds, such as RegenOx® and PersulfOx® by Regenesis Bioremediation Products. ISCO is applicable to treatment of chlorinated solvents, as well as a variety of other contaminants including petroleum hydrocarbons, polychlorinated biphenyls (PCBs), organochloride pesticides, and munitions.

The type of oxidant selected for an ISCO application depends, in part, on the subsurface conditions. Stronger oxidants have less persistence in the subsurface than weaker oxidants and are therefore more suitable for high permeability layers and hot spots. Permanganate and non-activated persulfate are more suitable for low permeability layers and diffuse contamination, while CHP and activated persulfate are more suitable in high permeability layers and hotspots.

Two advantages of ISCO over other conventional treatment technologies are that large volumes of waste material are not usually generated, and the treatment time is frequently much shorter.

4.3.3.1. ISCO Considerations at Alaska Real Estate Parking Lot

ERM assumed treatment of the PCE-impacted soil using a PersulfOx® solution. Tests indicate that PersulfOx® has a relatively longer active half-life than other oxidants, which will allow better distribution and treatment of soil, and that it is a relatively safe and easy to use ISCO. If ISCO is selected as the soil remedy, the actual oxidant selection will be based on bench-scale and pilot-scale testing results. Any cost differences are expected to be within the -50% to +100% cost range of this FS.

In addition to the data gaps presented in Section 4.2.5, the following items are also needed for proper design of an ISCO system:

- Natural oxidant demand or soil oxidant demand testing of subsurface soils and in particular the coal seam layers.
- Permeability testing and grain size analysis of the various subsurface materials.
- Bench scale and field pilot tests would be performed to evaluate the radius of influence for the injection points, to determine oxidant dosing requirements, and to refine assumptions regarding the number of applications required.

To treat the subsurface soils, the oxidant would be applied through injection points drilled down to a specified depth and injected at several depth intervals. Assuming that the coal layer represents a thin low permeability layer the distribution may be expected to pond and spread latterly across the layer providing a larger radius of influence. However, the distribution of oxidant within the coal layer may be poor if heterogeneities exist. Any distribution issues will likely result in the need to inject the oxidant several times to complete remediation.

4.3.3.2. Assumptions for Alternative S-3

Prior to completing the remedial design, bench-scale testing and a pilot test would be performed for ISCO. The primary goals of the bench-scale testing would be to evaluate distribution of oxidant within the subsurface soils, to more directly assess natural oxidant demand, and to evaluate different oxidants. The primary goals of the pilot test would be to assess realistic injection rates and oxidant distribution patterns/systems.

In Alternative S-3, the oxidant was assumed to be injected as an aqueous solution into a total of 54 injection points (based on a 15-foot radius of influence) (Figure 4B). The aqueous solution was assumed to have a concentration of approximately 3% oxidant. The chemical oxidation injections would occur over a 4-year period, with 25% of the total calculated oxidant demand injected each year. The purpose of the 4-year injection period is to optimize injection locations by allowing an assessment of the oxidant distribution between injections and thereby revising the injection geometry for subsequent injection events.

To calculate the amount of oxidant required, average soil TCE concentrations of 200 µg/Kg (for sand in both plumes) and 600 µg/Kg (for silt) and average groundwater TCE concentrations of 19 µg/L (MW-4 plume) and 175 µg/L (MW-5/7 plume) were assumed. The average value from Shannon & Wilson's oxidant demand analysis (7.4 g $KMnO_4$/kg soil plus groundwater) was used to calculate the natural oxidant demand (approximately 73,000 kg oxidant for 8E+06 kg soil and 1.9E+06 kg groundwater). The total amount of oxidant required for the contamination was calculated at approximately 8 kg.

For costing purposes, the soil treatment area was estimated at 28,000 square feet (Figure 5) with a treatment depth of 35 feet bgs. As the depth to groundwater varies between approximately 40 feet bgs and 45 feet bgs, there would be some vadose zone soils beneath the treatment area. It is assumed that soil treatment to a depth of 30 feet bgs would mitigate any vapor intrusion risk. It is also assumed that any remaining contaminants below 30 feet bgs that may still impact groundwater would be addressed via one of the groundwater treatment alternatives.

The primary assumptions used in preparing the cost estimate for chemical oxidation are listed as follows:

- Permanganate oxidant
- 5 gram per kilogram (g/kg) application rate (recommended RegenOx® application rate [2.5 g/kg] plus a 1.75 g/kg safety factor).
- 0.5% to 2% permanganate solution
- Surface application to treat the soil from 0 to 10 feet bgs will only be done in a couple of hot spots.
- Subsurface application via 20 injection points from 10 to 20 feet bgs (4,750 gallons per injection point) and 20 injection points screened from 25 to 35 feet bgs (3,000 gallons per injection point) using a GeoProbe driven injection device.

- Four annual applications of oxidant

The cost estimate assumes a three-year operation of the chemical oxidation system. O&M activities will include annual oxidant injections as described above and semiannual soil sampling and groundwater monitoring of ten monitoring wells for performance evaluation.

For costing purposes, it was assumed that the MNA/LTM groundwater monitoring schedule presented in Section 4.2.2 would also be followed.

4.3.4. S-4: In-Situ Thermal Remediation (ISTR)

4.3.5. S-5: Soil Excavation and Disposal

In Alternative S-5, the vadose-zone soil contaminated by PCE, TCE, or DCE above the ADEC Method Two cleanup level protective of the MTG pathway (i.e., most restrictive Method Two cleanup level) will be excavated for off-site treatment and disposal. Vapor intrusion risk will be partially mitigated and any remaining risk would be addressed by installing a subsurface slab depressurization (SSD) system in the crawl space or beneath any buildings as warranted. The soil treatment area is shown in Figure 5; it encompasses approximately 30,000 square feet of the site.

4.3.5.1. Excavation and Treatment of Contaminated Soil

Excavation is an ex situ technology in which the contaminated soil is removed from the site and the excavation area is backfilled with clean soil. The excavated soil would be treated and disposed of off-site in accordance with applicable laws and regulations (i.e., treatment and disposal of Resource Conservation and Recovery Act (RCRA) hazardous soil in a permitted landfill).

4.3.5.2. Assumptions for Alternative S-5

For costing purposes, an excavation volume of approximately 16,700 cubic yards (cy) was assumed. This volume is based on a 30,000-square-foot excavation area (Figure 5), an excavation depth of 15 feet bgs, and a 20% excavation expansion factor. An excavation depth of 15 feet was used due to practicability, cost, and feasibility. Other than the possible removal of surficial contamination (upper 15 feet of soil surface) excavation is not a feasible alternative for this site. Soil and groundwater contaminant levels extend to depths in excess of 50 feet below ground surface (bgs) and it would be prohibitively expensive even if it was technically feasible to remove soil to these depths.

As this alternative addresses only soil contamination present above the 15 foot depth, any soil contamination present below this depth will remain in place. Furthermore, soil contamination immediately beside or underneath buildings also cannot be removed without undermining the building. Underground sewer lines and other buried utilities are also expected to limit the volume of contaminated soil that can be excavated (Figure 7).

Field screening (using a Color-Tec instrument) will be used to guide the excavation. Excavation confirmation samples will be taken at a frequency of one sample per 500 square feet of excavation base, plus 10 percent duplicates, and analyzed for volatile organic compounds (VOCs).

The excavation will be backfilled and compacted with clean backfill from a local borrow source.

The excavated soil is assumed to be hazardous under RCRA, requiring shipping out of state for treatment and disposal at a permitted landfill in the lower 48. The excavated soil will be characterized by sampling at a frequency of one sample for each 100 cy of soil and analyzing for VOCs. Per RCRA, soil contaminated by PCE at a concentration above 6 mg/kg must be treated prior to disposal. This FS assumes that all excavated soil will be treated before disposal.

4.4. Groundwater Alternatives

The groundwater alternatives considered in the FS are listed in Section 4.1 and discussed in the following sections. The cost estimates for each alternative are provided in Appendix B.

4.4.1. GW-1: No Action

The No Action Alternative is used as a baseline reflecting current conditions without remediation. This alternative is used for comparison with each of the other alternatives.

4.4.2. GW-2: Monitored Natural Attenuation

Alternative GW-2 uses natural processes occurring in groundwater to reduce contaminant concentrations over time (MNA) and long-term monitoring (LTM) to track progress of the MNA and evaluate the remedy's effectiveness. As with the other alternatives, ICs will be used to protect human health until RAOs are reached.

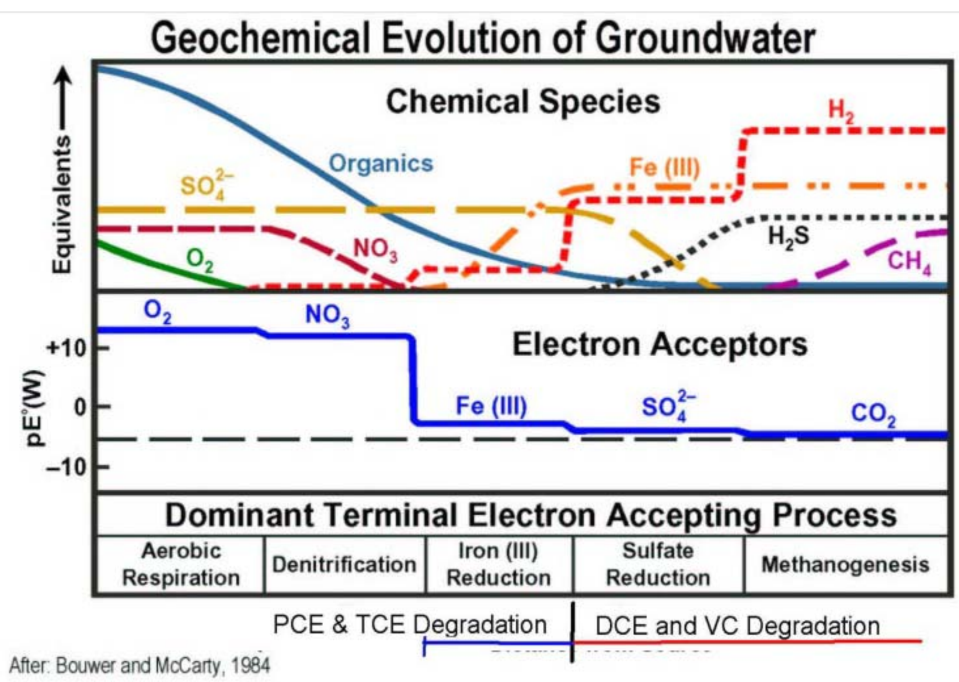
Dilution, adsorption, volatilization, precipitation, complexation, and biological degradation of the contaminants occur in the groundwater. Of these processes, reductive dechlorination (using biological and/or abiotic degradation processes) is usually the most significant degradation process for chlorinated solvents such as PCE and TCE. MNA would allow these processes to continue as they have in the past, without disturbances potentially caused by implementation of active remedial technologies.

4.4.2.1. Biological Degradation of PCE

The most important process for the natural biodegradation of the most highly chlorinated solvents (PCE and TCE) is reductive dechlorination. During this process, the chlorinated hydrocarbon is used as an electron acceptor, and a chlorine atom is removed and replaced with a hydrogen atom. In general, reductive dechlorination occurs by sequential dechlorination from PCE to TCE to DCE to vinyl chloride to ethene. Reductive dechlorination occurs in anaerobic groundwater conditions; the most rapid rates occur under highly reducing (sulfate-reducing and methanogenic) conditions (Wiedemeier, et. al. 1998), although reductive dechlorination has also been documented to occur under nitrate- and iron-reducing conditions. Because chlorinated hydrocarbons are used as electron acceptors during reductive dechlorination, there must be an appropriate source of carbon for microbial growth in order for this process to occur. Potential carbon sources include natural organic matter, fuel hydrocarbons, or other anthropogenic organic compounds.

The geochemical evolution of groundwater is shown in the diagram below. Dissolved oxygen (DO) is the most thermodynamically favored electron acceptor used by microbes for the biodegradation (oxidation) of organic carbon. During aerobic respiration, DO concentrations decrease in the groundwater. After depletion of DO, anaerobic microbes will use nitrate as an electron acceptor, followed by iron (and manganese, not shown on the diagram), sulfate, and finally carbon dioxide (methanogenesis). Each sequential reaction drives the oxidation-reduction potential of the groundwater downward into the range within which reductive dechlorination can occur. PCE and TCE degradation can occur in less reducing (i.e., iron-reducing) groundwater than DCE and vinyl chloride degradation (i.e., sulfate-reducing and methanogenic).

Although reductive dechlorination is the most prominent method for biological degradation of PCE and TCE, the daughter products DCE and vinyl chloride can be oxidized either anaerobically or aerobically. In fact, the aerobic oxidation rate of vinyl chloride is actually much faster than the anaerobic reductive dechlorination rate. Therefore, at some sites the optimal remedial technique is reductive dechlorination of PCE and TCE and possibly DCE, followed by downgradient oxidation of vinyl chloride, and possibly also DCE. Due to the dramatically different geochemical conditions required for reductive dechlorination and aerobic oxidation, combining these two



degradation mechanisms can be difficult.

4.4.2.2. MNA Considerations at Alaska Real Estate Parking Lot

The 1997 through 2012 groundwater sampling data at the site show that there has been some degradation of PCE to TCE at the site but DCE is not detected in the groundwater samples until it migrates to the former Alaska Native Hospital site (approximately 600 feet downgradient of the site). These sample results suggest that groundwater geochemistry is conducive to reductive dechlorination of PCE and possibly TCE but not DCE or vinyl chloride. However, vinyl chloride (22 µg/L) has been detected in groundwater at MW-28 once the plume nears the ML&P site and comingles with a petroleum hydrocarbon plume.

No geochemical parameter samples have been collected from the Alaska Real Estate Parking Lot site groundwater monitoring wells. However a limited amount of geochemical field parameter results have been collected and are discussed below.

- The DO and oxidation-reduction potential (ORP) measurements are variable, with indications of somewhat reducing groundwater conditions (DO less than 2 mg/L and negative ORP values) in some areas and oxidizing conditions (DO greater than 2 mg/L and positive ORP values) in other areas. For example, in 2008, the DO concentration in MW-2 was 3.7 mg/L with a positive ORP of 8 mV, indicating aerobic groundwater conditions; and the DO in WP-11 was 1.8 mg/L with a negative ORP of -125 mV (E&E, 2008). In general more reducing conditions were observed in monitoring wells located downgradient of the Alaska Real Estate Parking Lot site (i.e., former Alaska Native Hospital and other locations further downgradient).
- No groundwater total organic carbon (TOC), nitrate, iron, manganese, sulfate, methane or other natural attenuation parameter data have been collected at the site.

The presence of TCE degradation products in site groundwater samples is one line of evidence for MNA (reductive dechlorination). Historical groundwater monitoring results (E&E, 2008) indicate that very low concentrations of DCE have been detected in samples from three off site monitoring wells: WP-10, WP-11, and WP-12 (max of 0.98 µg/L). In addition, high concentrations of DCE and VC were detected in MW-28 (180 µg/L and 22 µg/L), respectively. The DCE and VC detections indicate that reductive dechlorination is occurring in some sections of the plume, most significantly at the downgradient portions of the plume near the former Alaska Native Hospital and beyond.

Overall, data suggest that PCE is being reduced to TCE onsite and DCE and VC in some downgradient portions of the plume. Geochemical parameter data indicate generally aerobic groundwater conditions near the site with more reducing groundwater conditions in the downgradient areas of the plume. Site data do not suggest that MNA (by reductive dechlorination) will be an effective remedy in the short-term, and it appears doubtful whether MNA can adequately treat groundwater contamination at the site in the long-term without some type of biostimulation enhancement.

4.4.2.3. Assumptions for Alternative GW-2

For costing purposes, it was assumed that the MNA groundwater monitoring schedule presented in Section 4.2.2 would be followed with the following modifications. The remediation timeframe was selected to be 35 years, because it is significantly longer than the longest remediation timeframe estimated for an active remedy (20 years), and because the present worth of costs beyond 35 years becomes insignificant. However, the 35-year timeframe is also somewhat arbitrary, because there has not yet been sufficient monitoring to establish a downward trend in groundwater contamination levels. If future monitoring shows that there are significant areas where reductive dechlorination is occurring at the site and soil remediation addresses most of the risk due to vapor intrusion, the remedial timeframe would be expected to be less than 35 years.

For costing purposes, it was assumed that 5 new monitoring wells would be installed for MNA monitoring. Quarterly MNA monitoring of 15 monitoring wells would be performed for one year followed by semiannual MNA monitoring for three years. Annual MNA monitoring of 15 monitoring wells would be performed for 15 years followed by groundwater monitoring every five years for the remaining time.

The primary risk associated with this alternative is the uncertainty about whether groundwater geochemistry is sufficiently reducing to effectively dechlorinate the PCE, TCE, and DCE to meet ADEC Table C groundwater cleanup levels at the site.

4.4.3. GW-3: In Situ Chemical Oxidation (ISCO)

In Alternative GW-3, a chemical oxidant would be injected into site groundwater to oxidize the contamination. Several different forms of oxidants have been used for ISCO, including permanganate (MnO_4^-), Fenton's hydrogen peroxide (H_2O_2) and ferrous iron (Fe^{+2}) or catalyzed hydrogen peroxide (CHP), ozone (O_3), and persulfate ($S_2O_8^{2-}$). In addition, there are proprietary oxidants, such as RegenOx® and PersulfOx® by Regenesis Bioremediation Products. All of these oxidants are considered effective for oxidizing PCE and its degradation products, TCE, DCE and vinyl chloride (ITRC, 2005).

4.4.3.1. ISCO Considerations at Alaska Real Estate Parking Lot

Shannon & Wilson assumed treatment of the TCE-impacted soil using a potassium permanganate ($KMnO_4$) solution. Potassium permanganate has a relatively longer half-life than other oxidants, which will allow better distribution. Natural oxidant demand tests performed on three saturated soil samples (SB-14, B-20/MW-7, and B-21/MW-8 from 31-33 feet bgs) showed the oxidant demand of subsurface organic and inorganic components in the soil and groundwater ranged from 3 to 14.6 grams of oxidant ($KMnO_4$) per kilogram of soil plus groundwater.

To treat the groundwater, the oxidant would be applied through injection points at a depth interval just above and into the groundwater (40 to 50 feet bgs). This distribution system would allow some oxidation of contaminants above the groundwater level, although the distribution of oxidant within the vadose zone would be expected to be poor. Similarly, it would be difficult or impossible to achieve a consistent oxidant “front” downgradient of the injection point. Instead, the oxidant would migrate into and through the saturated zone in channels/preferential pathways, resulting in incomplete oxidant distribution. Injection of the oxidant mixture may also be inhibited by precipitation of dissolved metals. The distribution issues will likely result in the need to inject the oxidant several times to complete remediation. Bench scale and field pilot tests would be performed to evaluate the radius of influence for the application wells, to determine oxidant dosing requirements, and to refine assumptions regarding the number of applications required.

4.4.3.2. Assumptions for Alternative GW-3

Prior to completing the remedial design, bench-scale testing and a pilot test would be performed for ISCO. The primary goals of the bench-scale testing would be to assess natural oxidant demand, and to evaluate different oxidants. The primary goals of the pilot test would be to assess realistic injection rates and oxidant distribution in the subsurface.

Potassium permanganate was the oxidant assumed for Alternative GW-3. Permanganate was selected based on its relatively greater persistence in the environment (greater than 3 months [Huling and Pivetz, 2006]) and therefore greater ability to diffuse through the low-permeability coal layers before degrading. If ISCO is selected as the groundwater remedy, the actual oxidant selection will be based on bench-scale and pilot-scale testing results. Any cost differences are expected to be within the -50% to +100% cost range of this FS.

In Alternative GW-3, the oxidant was assumed to be injected as an aqueous solution into a total of 54 injection points (based on a 15-foot radius of influence) (Figure 4B). The aqueous solution was assumed to have a concentration of approximately 3% oxidant. The injection rate was assumed to be up to approximately 20 liters per minute to help distribute the oxidant within the silt. The chemical oxidation injections would occur over a 4-year period, with 25% of the total calculated oxidant demand injected each year. The purpose of the 4-year injection period is to optimize injection locations by allowing an assessment of the oxidant distribution between injections and thereby revising the injection geometry for subsequent injection events.

To calculate the amount of oxidant required, average soil PCE concentrations of 200 µg/Kg and average groundwater TCE concentrations of 175 µg/L were assumed. The average value from Shannon & Wilson's oxidant demand analysis (7.4 g $KMnO_4$/kg soil plus groundwater) was used to calculate the natural oxidant demand (approximately 73,000 kg oxidant for 8E+06 kg soil and 1.9E+06 kg groundwater). The total amount of oxidant required for the contamination was calculated at approximately 8 kg.

For costing purposes, it was assumed that the MNA/LTM groundwater monitoring schedule presented in Section 4.2.2 would be followed. The remedial timeframe for Alternative GW-3 was estimated at ten years.

4.4.4. GW-4: Enhanced Reductive Dechlorination (ERD)

In Alternative GW-4, a substrate would be injected into site groundwater to enhance the biological degradation processes already occurring to a limited degree at the site. The purpose of the substrate addition is to promote fermentation reactions that then provide hydrogen as an electron donor for the dechlorination reactions. Hydrogen is generated by fermentation of non-chlorinated organic substrates, including naturally occurring organic carbon, accidental releases of anthropogenic carbon (fuel hydrocarbons), or introduced substrates such as alcohols, low-molecular-weight fatty acids, carbohydrates (sugars), vegetable oils, sodium lactate, and Hydrogen Release Compound [HRC™], among others. HRC™ is a viscous (honey-like), proprietary substance manufactured by Regenesis Corporation that, when hydrated, slowly releases lactic acid over a period of months. HRC™ is composed of glycerol tripolylactate, which is a nontoxic, food-grade substance. Because of its time-release feature, HRC™ requires less frequent injections than a soluble substrate like sodium lactate.

4.4.4.1. Enhanced Bioremediation Considerations

One consideration for enhanced bioremediation at this site is the ability to drive the groundwater plume to anaerobic conditions and maintain these conditions over time. The limited MNA field parameter results indicate that the site groundwater is generally aerobic, and there are likely significant competing electron acceptors that will need to be reduced before complete TCE reduction to ethene will occur. Groundwater sampling for dehalococcoides ethenogenes (DHC), which are the only known organisms capable of the complete dechlorination of DCE and VC to ethene, has not been performed at the site.

Another consideration for this site is that a majority of the groundwater plume is located off-site. Long-term access for injection and monitoring well networks will be necessary for successful implementation of any groundwater treatment technology, including ISCO and ERD.

4.4.4.2. Assumptions for Alternative GW-4

Prior to completing the remedial design at the Aniak WACS site, bench-scale testing and a pilot test would be performed for ERD. The primary goals of the bench-scale testing would be to evaluate the performance of different electron donors (substrates) and bioaugmentation on reductive dechlorination using site soils and groundwater. The primary goals of the pilot test would be to assess realistic injection rates and substrate distribution in the contaminant plume.

For costing purposes, it was assumed that HRC™ would be the substrate injected at this site. However, other substances would likely work as well, or better. For example, Regenesis has also developed a substance called HRC Primer™, which is less viscous and more readily bioavailable than HRC™. Regenesis recommends use of HRC Primer™ to initiate the remedial process at some sites. Because it is less viscous than HRC™, HRC Primer™ is expected to have better distribution in tighter, less-permeable soil layers than HRC™. However, HRC Primer™ will require more frequent reinjection than HRC™. There are also nonproprietary substances such as sodium lactate or emulsified vegetable oil or combinations of substances that could be used. If Alternative GW-4 is selected for groundwater remediation at this site, microcosm and/or pilot testing would be used to select the actual substrate to inject.

An online calculator provided by Regenesis (www.regonlinesoft.com) was used to estimate the volume of HRC™ required for this alternative. To calculate the amount of substrate required, an average soil TCE concentration of 200 µg/Kg was assumed for sand in both plumes, a groundwater TCE concentration of 19 µg/L was assumed for the MW-4 plume, a TCE concentration of 600 µg/Kg was assumed for the silt in the MW-5/7 plume, and a groundwater TCE concentration of 175 µg/L was assumed for the MW-5/7 plume. Typical geochemical parameter values from other Alaskan sites were used to calculate the competing electron acceptor concentrations: 3.0 mg/L oxygen, 1.0 mg/L nitrate, 5 mg/L manganese, 128 mg/L iron, 10 mg/L sulfate, and xx mg/L methane.

The remedial design for enhanced bioremediation was consistent with the design of ISCO; i.e., a 15-foot radius of influence resulting in a total of 42 injection wells in the upper plume (Figure 4B). Based on these assumptions, the Regenesis calculator determined a total requirement of 3,800 pounds of HRC™. A closer injection spacing is expected to be necessary to increase substrate distribution within the subsurface; therefore, the remedial design includes an initial injection of 3,800 pounds of HRC™ followed by three additional annual injections of 2,850 pounds of HRC™ each (i.e., 75% of the initial injection mass), for a total of 12,350 pounds of HRC™.

This alternative also includes bioaugmentation (i.e., injection of appropriate microbial community [DHC organisms]) for complete reductive dechlorination of TCE to ethene. The presence or absence of DHC organisms is unknown at this site, but bioaugmentation was included in the cost estimate. Bioaugmentation is relatively inexpensive relative to the entire project cost, and it may assist and will not hurt reductive dechlorination at the site. For costing purposes, one bioaugmentation event of 100 liters of KB-1® dechlorinator was assumed. KB-1® injection should not occur until the aquifer has been driven anaerobic; therefore the bioaugmentation was considered to occur in years 1. KB-1® is a naturally occurring, non-pathogenic microbial culture that contains DHC, the only group of microorganisms documented to promote the complete dechlorination of chlorinated ethenes to non-toxic ethene. KB-1® is used to establish complete dechlorination at sites that do not contain DHC (or the right DHC) and to accelerate dechlorination rates to achieve treatment goals. As with the other assumptions in this FS, selection of the actual microbial consortium for injection would occur after additional characterization and in conjunction with a pilot test.

For costing purposes, it was assumed that the MNA/LTM groundwater monitoring schedule presented in Section 4.2.2 would be followed. The remedial timeframe for Alternative GW-4 was estimated at twenty years.

4.4.5. GW-5: Permeable Reactive Barrier

Alternative GW-5 involves air sparging in conjunction with SVE, as evaluated by Shannon & Wilson (2010a). Air sparging is an in-situ technology in which air is injected into a contaminated aquifer using air sparge wells to induce volatilization of contaminants. As air moves through the saturated soil within the zone of influence of the air sparge wells, volatile organic contaminants are stripped from the water. Using an SVE system in conjunction with air sparge will enhance the process by increasing flow through the groundwater, controlling gas/vapor movement through the subsurface, and capturing volatiles before they escape at the surface.

4.4.5.1. Permeable Reactive Barrier Considerations

Shannon & Wilson performed an air sparge pilot test that showed that air could be injected into the water-bearing zone beneath the silt with a radius of influence of about 20 feet. However, they also identified that air sparge may not be an effective remedial alternative as the contaminated groundwater is located in a semiconfined aquifer system. The silt layer overlying the saturated sandy gravel to gravelly sand soil may act as an aquitard, creating semi-confined conditions. Air injected into the semi-confined aquifer could become trapped by the overlying, semi-confining layer and may not be able to escape to the unsaturated zone for capture using SVE wells. However, the competence of the silt layer has not been determined, so the degree to which it may act as an aquitard is not known.

4.4.5.2. Assumptions for Alternative GW-5

To ensure that the assumptions used in the air sparge alternative were consistent with the assumptions in Alternatives GW-2 through GW-4, OASIS revised the cost estimate prepared by Shannon & Wilson (2010). In particular, revisions were made to the monitoring schedule and system installation costs. The assumptions for Alternative GW-5 are discussed below.

Consistent with Alternatives GW-3 and GW-4, GW-5 assumes that an air sparge pilot test would be performed prior to remedial system design. Although an air sparge pilot test has been performed at the Aniak WACS site, a second pilot test would be necessary to specifically assess the radius of influence in the silt layer in the most highly-contaminated portion of the site (i.e., between the former truck fill area and SGP-17).

The physical assumptions of Alternative GW-5 are consistent with Shannon & Wilson's physical assumptions, i.e., 15 sparge wells to a total depth of 45 feet bgs (Figure 4B). Costs for the SVE component are already included in the SVE soil remediation and are therefore not repeated in groundwater alternative GW-5. After the first year of operation, the sparge system power requirement was assumed to drop to 50% of the initial power requirement due to system cycling. Blower replacement was assumed every 5 years, with complete sparge system well replacement after ten years.

For costing purposes, it was assumed that the MNA/LTM groundwater monitoring schedule presented in Section 4.2.2 would be followed. The remedial timeframe for Alternative GW-5 was estimated at twenty years.

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5. SUMMARY OF COMPARATIVE ANALYSIS OF ALTERNATIVES

5.1. Evaluation Criteria

The five groundwater remedial alternatives identified in the previous section of this Focused FS were evaluated against the nine criteria described in Section 121(b) of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and the National Contingency Plan (NCP) §300.430(f)(5)(i). The CERCLA criteria are classified as threshold criteria, balancing criteria, and modifying criteria.

Threshold criteria are standards that an alternative must meet to be eligible for selection as a remedial action. There is little flexibility in meeting the threshold criteria—the alternative must meet them or it is unacceptable. The following are classified as threshold criteria:

- Overall protection of human health and the environment
- Compliance with regulations

Balancing criteria weigh the tradeoffs between alternatives. These criteria represent the standards upon which the detailed evaluation and comparative analysis of alternatives are based. In general, a high rating on one criterion can offset a low rating on another balancing criterion. Five of the nine criteria are considered balancing criteria:

- **Long-term effectiveness and permanence**: This criterion refers to expected residual risk and the ability of a remedy to maintain reliable protection of human health and the environment over time, after the remedy has been completed.
- **Reduction of toxicity, mobility, and volume through treatment**: This criterion evaluates the anticipated performance of the treatment technologies that may be included as part of a remedy.
- **Short-term effectiveness**: This criterion addresses the effectiveness of the remedy during its implementation. It includes the period of time needed to implement the remedy along with any adverse impacts that may be posed to workers, the community, and the environment during construction and operation of the remedy until cleanup levels are achieved.
- **Implementability**: This criterion addresses the technical and administrative feasibility of a remedy from design through construction and operation. Factors such as availability of services and materials, administrative feasibility, and coordination with other governmental entities are also considered.
- **Cost:** This criterion addresses the cost-effectiveness of a remedy based upon design, construction, start-up, monitoring, and maintenance costs.

Modifying criteria evaluate public acceptance and can therefore not be considered in the FS. The final two criteria are considered modifying criteria**:**

- Community acceptance
- State/regulatory agency acceptance

5.2. Comparative Analysis of Alternatives

A comparative analysis was performed to identify the advantages and disadvantages of each alternative relative to the other alternatives. The relative performance of each alternative was evaluated with respect to each of the NCP criteria. The scoring procedure is discussed in this section.

Threshold criteria are either met or not met; therefore, "yes" and "no" were used as the scores for threshold criteria.

A numerical scoring scheme was used for evaluating the balancing criteria. Each alternative was assigned a numerical score between 0 and 5 for each criterion to reflect the expected performance of the alternative. The scores have no independent value; they are only meaningful when compared among the different alternatives. The numerical scores are presented and defined below:

0: Worst (Criterion not satisfied)

1: Poor

2: Below Average

3: Average (Criterion partially satisfied)

4: Above Average

5: Best (Criterion completely satisfied)

All of the criteria except cost were evaluated on a qualitative basis. Cost was evaluated quantitatively by calculating the expected range of costs (within a range of -50% to +100%) and then normalizing the costs to the 0 to 5 scale, with the least expensive alternative receiving a score of 5, and the most expensive alternative receiving a score of 0. The quantitative cost evaluation was performed based on the EPA document entitled *A Guide to Developing and Documenting Cost Estimates During the Feasibility Studies* (EPA, 2000).

5.3. Comparison of Soil Alternatives

The numerical scores of the five soil alternatives for the nine NCP criteria are presented in Table 5-1 and discussed in this section. As discussed in Section 4.2.1, OM&M costs for continued operation of a vapor intrusion mitigation system for the duration of each soil remedy or until vapor intrusion risks are mitigated are included in the cost evaluation.

Table 5-1: Comparative Analysis of Soil Alternatives

Remedial Alternative		Threshold Criteria		Effectiveness Scores				Cost				
Identifier	Description	Protection of Human Health and the Environment	Compliance with ARARs	Long-term Effectiveness and Permanence	Reduction in Toxicity, Mobility, and Volume through Treatment	Short-term Effectiveness	Implementability	Cost Score	Estimated Present Worth Range (-50% to + 100%) (in thousands of dollars)	**Effectiveness Total**	**Total Score**	**Effectiveness to Cost Quotients**
Soil Alternatives												
S-1	No Action	No	No	0.0	0.0	0.0	5.0	5.0	\$0 \$0	0.0	10.0	NA
S-2	Soil Vapor Extraction	Yes	Yes	2.0	2.0	3.3	4.0	2.2	\$1,217 \$4,870	7.3	13.5	0.60 0.15
S-3	ISCO (Chemical Oxidation)	Yes	Yes	4.0	4.0	2.5	3.0	0.0	\$2,152 \$8,608	10.5	13.5	0.49 0.12
S-4	ISTR (Thermal Remediation)	Yes	Yes	3.5	3.0	3.3	3.0	1.0	\$1,715 \$6,858	9.8	13.8	0.57 0.14
S-5	Soil Excavation	Yes	Yes	2.5	2.0	2.5	2.0	0.8	\$1,813 \$7,252	7.0	9.8	0.39 0.10

Explanation of Scores:

0	Worst (Criterion not satisfied)	3	Average
1	Poor	4	Above Average
2	Below Average	5	Best (Criterion completely satisfied)

5.3.1. Threshold Criteria

5.3.1.1. Protection of Human Health and the Environment

Alternative S-1 (No Action) is not expected to protect human health or the environment and received a score of “**no**” for this criterion.

The other four alternatives (S-2 through S-5) are expected to provide protection of human health and the environment. For all alternatives S-2 through S-5, continued operation of a system that will mitigate vapor intrusion risk is assumed, and ICs will be used as necessary to protect human health until soil and groundwater RAOs are met. All four soil alternatives S-2 through S-5 are expected to reduce impacts to groundwater however by themselves none would be expected to ensure protectiveness of groundwater, at least in the short term. Therefore it is assumed that one of the groundwater remediation alternatives would also be chosen to satisfy the protectiveness of groundwater component. Alternatives S-2 through S-5 received a score of “**yes**” for this criterion.

5.3.1.2. Compliance with Regulations

Alternative GW-1 (No Action) is not expected to meet ADEC Table C cleanup levels and received a score of “**no**” for this criterion.

Evaluating compliance with regulations for the other four alternatives required an assumption that an alternative point of compliance could be established for the source area. It is possible that none of the alternatives will be able to meet ADEC Table B1 cleanup levels throughout the site, depending on the amount of contamination held in the vadose zone and coal lens and the permeability of the coal lens layers, both of which have not yet been assessed. However through contaminant mass reduction it is anticipated that all four of the alternatives could reduce contaminant migration to below cleanup levels at selected compliance monitoring locations.

All four alternatives S-2 through S-5 are expected to eventually meet ADEC Table B1 cleanup levels if alternative points of compliance or an overall mass reduction amount (i.e., contaminant flux to groundwater and soil gas) were established for the source area and therefore received scores of “**yes**” for this criterion. Alternatives S-3 (ISCO) and S-4 (ISTR) are considered to meet cleanup levels to the maximum extent practicable for the site and therefore are considered to be compliant with regulations. There is greater uncertainty to meet compliance with Alternatives S-2 (SVE) and S-5 (Excavation – since contamination below 15 feet would remain); this uncertainty is reflected in lower balancing criteria scores discussed below.

5.3.2. Balancing Criteria

5.3.2.1. Long-Term Effectiveness

Alternative S-1 (No Action) does not provide any soil treatment and is not expected to protect human health or the environment in the long-term and received a score of “0” for long-term effectiveness.

Alternatives S-3 (ISCO) and S-4 (ISTR) are expected to treat most of the soil contaminated by PCE to below the ADEC Table B1 cleanup levels to the maximum extent practicable. For these alternatives, distribution of the oxidant (S-3) and volatilization of contaminants through thermal heating of the soil (S-4) in the high TOC potentially low-permeability coal layer is considered the most difficult part of the remedy. To the degree that the oxidant can be distributed within the silt layer, both ISCO and ISTR are considered effective remedies. Alternative S-3 is ranked the highest (“4”) for long-term effectiveness, because there are no expected impediments to effective soil treatment using ISCO other than distribution concerns. The ISTR alternative (S-4) is ranked “3.5,” because ISTR requires activity from microbial communities whose activity has not been confirmed at this site and whose effectiveness may be adversely affected by the cold groundwater temperatures but are ultimately expected to be capable of mediating complete reductive dechlorination of the TCE. Both ISCO and ISTR are considered permanent remedies that are effective in the long-term and not reversible.

The soil vapor extraction alternative (S-2) received a score of “3” for long-term effectiveness. The effectiveness of SVE is expected to be limited by the high TOC coal layers and heterogeneities in the soil permeability. In areas of the site where the coal layer is not present, SVE would be expected to be effective. However, even in highly-permeable soils, the extracted air tends to travel in preferential pathways, creating a challenge to complete soil treatment. SVE is considered a permanent remedy that is effective in the long-term and not reversible.

The soil excavation alternative (S-5) received a score of “2” for long-term effectiveness. Soil excavation is considered a permanent and effective remedy; however, only 15 feet of the 45 to 50 foot plus thickness of PCE contaminated soil is to be removed. Approximately 70 percent plus of the PCE contamination will remain and the depths of highest contamination (i.e., 25 to 30 feet bgs) . The uncertainty of this alternative is reflected in the long-term effectiveness score of “2.”

5.3.2.2. Reduction in Toxicity, Mobility, and Volume through Treatment

Alternative GW-1 (No Action) does not provide any treatment, so it received a score of “0” for reduction in toxicity, mobility, and volume through treatment.

The remaining alternatives are expected to treat most of the groundwater contaminated by TCE to below the ADEC Table C cleanup levels as described below.

- The ISCO alternative (GW-3) is ranked highest (“4”) for reduction in toxicity, mobility, and volume through treatment, because it results in the immediate destruction of the contaminant where contacted.

- The ERD alternative (GW-4) is received a score of "3" for reduction in toxicity, mobility, and volume through treatment. It relies on activity from a microbial community whose activity has not been confirmed at this site and whose effectiveness may be adversely affected by the cold groundwater temperatures but are ultimately expected to be capable of mediating complete reductive dechlorination of the TCE. In addition, ERD creates toxic intermediate daughter products (i.e., vinyl chloride) whose presence is expected to be of limited duration but must be managed properly. ERD provides the carbon source that is necessary for the reductive dechlorination and therefore has a higher likelihood of effectively treating groundwater than MNA alone.
- The air sparge alternative (GW-5) received a score of "2," because air sparging does not actually treat the TCE contamination but instead volatilizes it to air. In addition, there is uncertainty about whether the TCE volatilized below the silt layer can be effectively captured and removed from the site through SVE rather than simply readsorbing to the silt. Air sparging is not expected to be effective within the silt layer due to its high water saturation and resulting low permeability to air.
- The MNA alternative (GW-2) received a score of "2" for this criterion. MNA reduces toxicity, mobility, and volume of contamination; however, its effectiveness is dependent upon anaerobic groundwater conditions and the presence of a carbon source. The analytical evidence suggests that elevated oxygen and low organic carbon content in the aquifer may be limiting factors for effective and complete degradation of TCE to its non-toxic endpoint, ethene.

5.3.2.3. Short-Term Effectiveness

Alternative GW-1 (No Action) does not provide any treatment. Although the community, workers, and environment do not incur any added risks due to this remedy, there is an infinite time frame until remedy completion. Alternative GW-1 received a score of "0" for short-term effectiveness.

As discussed previously, the short-term effectiveness criterion contains two main components: protection of the community, workers, and environment during remedy implementation, and time until remedy completion. The ranking of alternatives for these two components is nearly opposite each other, resulting in similar overall short-term effectiveness scores. These components are discussed separately below with respect to Alternatives GW-2 through GW-5.

Regarding the first component (protection during remedy implementation), Alternative GW-2 (MNA/LTM) is the most protective, because it involves very little risk due to remedy construction. The only exposure to groundwater contamination would be from groundwater monitoring; this exposure can be readily mitigated by appropriate worker health and safety procedures. Added risks from implementation of Alternative GW-4 (ERD) result from handling of the substrate, although the substrate handling risks are considered minor, because it is not reactive. Alternative GW-5 (Air Sparging) volatilizes

TCE and daughter products that were previously dissolved in water, resulting in added vapor inhalation risks. This risk can be mitigated by capturing the volatilized chemicals through the SVE system; however, the silt layer increases the uncertainty of complete capture. Added risks to the community from Alternative GW-3 (ISCO) result from handling of the oxidant. The reactivity of the oxidant will pose increased risk to workers relative to the other alternatives, although the risk can be mitigated with appropriate health and safety procedures.

Regarding the second component (remedy time frame), Alternative GW-3 (ISCO) is superior to the other alternatives, because it offers the shortest time to remedy completion (ten years). Alternatives GW-4 (ERD) and GW-5 (air sparging) have equal times to remedy completion (20 years). The time frame for air sparging is expected to be lengthy, because treatment of contamination located in the silt and sand layers away from the preferential pathways for air flow is diffusion-limited. The lengthy time frame assumed for the ERD alternative is based on the need to establish and maintain reducing geochemical conditions and an active microbial community of reductive dechlorinators. Also, the cold groundwater temperatures are expected to lengthen treatment time relative to treatment in warmer temperatures. The time frame until remedy completion using MNA (GW-2) is uncertain and likely to take many years; a remediation timeframe of 35 years was assumed.

Based on the two components of short-term effectiveness, the overall short-term effectiveness scores for Alternatives GW-2 and GW-4 are “3.3,” whereas the overall short-term effectiveness for the other alternatives is “2.5.”

5.3.2.4. Implementability

There are no technical or administrative barriers to implementation of Alternative GW-1 (No Action). Alternative GW-1 received the maximum score of “5” for this criterion.

Alternative GW-2 (MNA) received an implementability score of “4.” There are no significant barriers to implementing MNA at this site, but groundwater sampling and analysis is required. Alternatives GW-3 and GW-4 both received scores of “3” for this criterion, because they involve similar implementation tasks such as drilling, plumbing, monitoring, and logistics. Alternative GW-5 received an implementatbility score of “2,” because of expected implementability difficulties associated with the silt layer. If the silt layer is higly competent and continuous across the site, then air sparging would be considered to be poorly implementable and earn a score of “1;” however, the competency and extent of the silt layer is unknown. Alternatives GW-3, GW-4, and GW-5 all involve obtaining property owner consent and drilling multiple injection or extraction wells at this site.

5.3.2.5. Cost

The relative cost scores of the three groundwater alternatives are presented in Table 5-1, and detailed cost spreadsheets are presented in Appendix B.

There are no costs associated with Alternative S-1; therefore, it received the maximum normalized score of “5” for the cost criterion. Alternative GW-3 (ISCO) was the most expensive alternative ($2,200,000 to $8,600,000); therefore, it received the minimum normalized score of “0” for this criterion. Excluding the No Action Alternative, Alternative GW-2 (MNA/LTM) was the least expensive ($1,200,000 to $4,900,000) and received a cost score of “2.2.” Alternatives GW-4 (ERD) ($1,700,000 to $6,900,000) and GW-5 (Air Sparge) ($1,800,000 to $7,300,000) received cost scores of “1.0” and “0.8,” respectively.

5.4. Comparison of Groundwater Alternatives

The numerical scores of the five groundwater alternatives for the nine NCP criteria are presented in Table 5-2 and discussed in this section. All of the groundwater alternatives assume implementation of the planned vadose zone remedies and continued operation of the vapor mitigation system for the duration of the groundwater remedy, i.e., until groundwater RAOs have been met. As discussed in Section 4.2.1, OM&M costs for continued operation of the vapor mitigation system for the duration of each groundwater remedy are included in the cost evaluation. Impacts to vadose zone soil and vapor intrusion risk by the groundwater remedies is not considered in the following analysis, except to the extent that the groundwater remedy may directly impact the vadose zone or vapor intrusion.

Table 5-2: Comparative Analysis of Groundwater Alternatives

Remedial Alternative		Threshold Criteria		Effectiveness Scores			Implementability	Cost		**Effectiveness Total**	**Total Score**	**Effectiveness to Cost Quotients**
Identifier	Description	Protection of Human Health and the Environment	Compliance with ARARs	Long-term Effectiveness and Permanence	Reduction in Toxicity, Mobility, and Volume through Treatment	Short-term Effectiveness		Cost Score	Estimated Present Worth Range (-50% to + 100%) (in thousands of dollars)			
Groundwater Alternatives												
GW-1	No Action	No	No	0.0	0.0	0.0	5.0	5.0	\$0 \$0	0.0	10.0	NA
GW-2	LTM/MNA	Yes	Yes	2.0	2.0	3.3	4.0	2.2	\$1,217 \$4,870	7.3	13.5	0.60 0.15
GW-3	ISCO (Chemical Oxidation)	Yes	Yes	4.0	4.0	2.5	3.0	0.0	\$2,152 \$8,608	10.5	13.5	0.49 0.12
GW-4	ERD (Substrate Addition)	Yes	Yes	3.5	3.0	3.3	3.0	1.0	\$1,715 \$6,858	9.8	13.8	0.57 0.14
GW-5	Permeable Reactive Barrier	Yes	Yes	2.5	2.0	2.5	2.0	0.8	\$1,813 \$7,252	7.0	9.8	0.39 0.10

Explanation of Scores:

0 Worst (Criterion not satisfied)
1 Poor
2 Below Average
3 Average
4 Above Average
5 Best (Criterion completely satisfied)

5.4.1. Threshold Criteria

5.4.1.1. Protection of Human Health and the Environment

Alternative GW-1 (No Action) is not expected to protect human health or the environment and received a score of "**no**" for this criterion.

The other four alternatives (GW-2 through GW-5) are expected to provide protection of human health and the environment. For all alternatives GW-2 through GW-5, continued operation of the SSD system will mitigate vapor intrusion risk, and ICs will be used as necessary to protect human health until groundwater RAOs are met. Although there are drinking water wells near the site, pumping tests and datalogger studies suggest minimal groundwater migration is occuring. There is no evidence that groundwater contamination will migrate to the drinking water wells under current conditions, and none of the alternatives are expected to increase plume migration. The monitoring component of all four alternatives GW-2 through GW-5 would be used to monitor any plume migration and thereby ensure protectiveness. Alternatives GW-2 through GW-5 received a score of "**yes**" for this criterion.

5.4.1.2. Compliance with Regulations

Alternative GW-1 (No Action) is not expected to meet ADEC Table C cleanup levels and received a score of "**no**" for this criterion.

Evaluating compliance with regulations for the other four alternatives required an assumption that an alternative point of compliance could be established downgradient of the source area. It is possible that none of the alternatives will be able to meet ADEC Table C cleanup levels throughout the site, depending on the amount of contamination held in the silt layer and the permeability of the silt layer, both of which have not yet been assessed.

All four alternatives GW-2 through GW-5 are expected to eventually meet ADEC Table C cleanup levels if a point of compliance were established downgradient of the source area and therefore received scores of "**yes**" for this criterion. Alternatives GW-3 (ISCO) and GW-4 (ERD) are considered to meet cleanup levels to the maximum extent practicable for the site and therefore are considered to be compliant with regulations. There is greater uncertainty to meet compliance with Alternatives GW-2 (MNA) and GW-5 (SVE); this uncertainty is reflected in lower balancing criteria scores discussed below.

5.4.2. Balancing Criteria

5.4.2.1. Long-Term Effectiveness

Alternative GW-1 (No Action) does not provide any groundwater treatment and is not expected to protect human health or the environment in the long-term and received a score of "0" for long-term effectiveness.

Alternatives GW-3 (ISCO) and GW-4 (ERD) are expected to treat most of the groundwater contaminated by TCE to below the ADEC Table C cleanup levels to the maximum extent practicable. For these alternatives, distribution of the oxidant (GW-3) and substrate (GW-4) in the low-permeability silt layer is considered the most difficult part of the remedy. To the degree that the oxidant and/or substrate can be distributed within the silt layer, both ISCO and ERD are considered effective remedies. For comparison purposes, the silt layer is expected to similarly affect alternatives GW-3 and GW-4. Alternative GW-3 is ranked the highest ("4") for long-term effectiveness, because there are no expected impediments to effective groundwater treatment using ISCO other than distribution concerns. The ERD alternative (GW-4) is ranked "3.5," because ERD requires activity from microbial communities whose activity has not been confirmed at this site and whose effectiveness may be adversely affected by the cold groundwater temperatures but are ultimately expected to be capable of mediating complete reductive dechlorination of the TCE. Both ISCO and ERD are considered permanent remedies that are effective in the long-term and not reversible.

The air sparge alternative (GW-5) received a score of "2.5" for long-term effectiveness. The effectiveness of air sparging is expected to be limited by the silt layer. In areas of the site where the silt layer is not present or not highly-competent, air sparging would be expected to be effective. However, even in highly-permeable soils, the sparged air tends to travel in preferential pathways, creating a challenge to complete groundwater treatment. Air sparging is not expected to be effective for addressing contamination within the silt layer, because the relatively high expected water saturation levels will create a barrier to air flow. Air sparging is considered a permanent remedy that is effective in the long-term and not reversible.

The MNA alternative (GW-2) received a score of "2" for long-term effectiveness. MNA is considered a permanent and effective remedy; however, the effectiveness of reductive dechlorination (the primary biological component of MNA for TCE) is dependent upon anaerobic groundwater conditions and the presence of a carbon source. The analytical evidence suggests that organic carbon content in the aquifer may be a limiting factor for effective and complete degradation of TCE to its non-toxic endpoint, ethene. Also, the analytical evidence suggests that aerobic groundwater conditions are present across most of the site, at least at high water levels. The uncertainty of this alternative is reflected in the long remedial timeframe (35 years) as well as the long-term effectiveness score of "2."

5.4.2.2. Reduction in Toxicity, Mobility, and Volume through Treatment

Alternative GW-1 (No Action) does not provide any treatment, so it received a score of "0" for reduction in toxicity, mobility, and volume through treatment.

The remaining alternatives are expected to treat most of the groundwater contaminated by TCE to below the ADEC Table C cleanup levels as described below.

- The ISCO alternative (GW-3) is ranked highest ("4") for reduction in toxicity, mobility, and volume through treatment, because it results in the immediate destruction of the contaminant where contacted.

- The ERD alternative (GW-4) is received a score of "3" for reduction in toxicity, mobility, and volume through treatment. It relies on activity from a microbial community whose activity has not been confirmed at this site and whose effectiveness may be adversely affected by the cold groundwater temperatures but are ultimately expected to be capable of mediating complete reductive dechlorination of the TCE. In addition, ERD creates toxic intermediate daughter products (i.e., vinyl chloride) whose presence is expected to be of limited duration but must be managed properly. ERD provides the carbon source that is necessary for the reductive dechlorination and therefore has a higher likelihood of effectively treating groundwater than MNA alone.
- The air sparge alternative (GW-5) received a score of "2," because air sparging does not actually treat the TCE contamination but instead volatilizes it to air. In addition, there is uncertainty about whether the TCE volatilized below the silt layer can be effectively captured and removed from the site through SVE rather than simply readsorbing to the silt. Air sparging is not expected to be effective within the silt layer due to its high water saturation and resulting low permeability to air.
- The MNA alternative (GW-2) received a score of "2" for this criterion. MNA reduces toxicity, mobility, and volume of contamination; however, its effectiveness is dependent upon anaerobic groundwater conditions and the presence of a carbon source. The analytical evidence suggests that elevated oxygen and low organic carbon content in the aquifer may be limiting factors for effective and complete degradation of TCE to its non-toxic endpoint, ethene.

5.4.2.3. Short-Term Effectiveness

Alternative GW-1 (No Action) does not provide any treatment. Although the community, workers, and environment do not incur any added risks due to this remedy, there is an infinite time frame until remedy completion. Alternative GW-1 received a score of "0" for short-term effectiveness.

As discussed previously, the short-term effectiveness criterion contains two main components: protection of the community, workers, and environment during remedy implementation, and time until remedy completion. The ranking of alternatives for these two components is nearly opposite each other, resulting in similar overall short-term effectiveness scores. These components are discussed separately below with respect to Alternatives GW-2 through GW-5.

Regarding the first component (protection during remedy implementation), Alternative GW-2 (MNA/LTM) is the most protective, because it involves very little risk due to remedy construction. The only exposure to groundwater contamination would be from groundwater monitoring; this exposure can be readily mitigated by appropriate worker health and safety procedures. Added risks from implementation of Alternative GW-4 (ERD) result from handling of the substrate, although the substrate handling risks are considered minor, because it is not reactive. Alternative GW-5 (Air Sparging) volatilizes

TCE and daughter products that were previously dissolved in water, resulting in added vapor inhalation risks. This risk can be mitigated by capturing the volatilized chemicals through the SVE system; however, the silt layer increases the uncertainty of complete capture. Added risks to the community from Alternative GW-3 (ISCO) result from handling of the oxidant. The reactivity of the oxidant will pose increased risk to workers relative to the other alternatives, although the risk can be mitigated with appropriate health and safety procedures.

Regarding the second component (remedy time frame), Alternative GW-3 (ISCO) is superior to the other alternatives, because it offers the shortest time to remedy completion (ten years). Alternatives GW-4 (ERD) and GW-5 (air sparging) have equal times to remedy completion (20 years). The time frame for air sparging is expected to be lengthy, because treatment of contamination located in the silt and sand layers away from the preferential pathways for air flow is diffusion-limited. The lengthy time frame assumed for the ERD alternative is based on the need to establish and maintain reducing geochemical conditions and an active microbial community of reductive dechlorinators. Also, the cold groundwater temperatures are expected to lengthen treatment time relative to treatment in warmer temperatures. The time frame until remedy completion using MNA (GW-2) is uncertain and likely to take many years; a remediation timeframe of 35 years was assumed.

Based on the two components of short-term effectiveness, the overall short-term effectiveness scores for Alternatives GW-2 and GW-4 are “3.3,” whereas the overall short-term effectiveness for the other alternatives is “2.5.”

5.4.2.4. Implementability

There are no technical or administrative barriers to implementation of Alternative GW-1 (No Action). Alternative GW-1 received the maximum score of “5” for this criterion.

Alternative GW-2 (MNA) received an implementability score of “4.” There are no significant barriers to implementing MNA at this site, but groundwater sampling and analysis is required. Alternatives GW-3 and GW-4 both received scores of “3” for this criterion, because they involve similar implementation tasks such as drilling, plumbing, monitoring, and logistics. Alternative GW-5 received an implementatbility score of “2,” because of expected implementability difficulties associated with the silt layer. If the silt layer is higly competent and continuous across the site, then air sparging would be considered to be poorly implementable and earn a score of “1;” however, the competency and extent of the silt layer is unknown. Alternatives GW-3, GW-4, and GW-5 all involve obtaining property owner consent and drilling multiple injection or extraction wells at this site.

5.4.2.5. Cost

The relative cost scores of the three groundwater alternatives are presented in Table 5-1, and detailed cost spreadsheets are presented in Appendix C.

There are no costs associated with Alternative GW-1; therefore, it received the maximum normalized score of “5” for the cost criterion. Alternative GW-3 (ISCO) was the most expensive alternative ($2,200,000 to $8,600,000); therefore, it received the minimum normalized score of “0” for this criterion. Excluding the No Action Alternative, Alternative GW-2 (MNA/LTM) was the least expensive ($1,200,000 to $4,900,000) and received a cost score of “2.2.” Alternatives GW-4 (ERD) ($1,700,000 to $6,900,000) and GW-5 (Air Sparge) ($1,800,000 to $7,300,000) received cost scores of “1.0” and “0.8,” respectively.

5.5. Preferred Alternatives

In addition to the individual criteria scores discussed above, there are three comparison tools presented in Table 5-1 that may be used to help select the preferred alternative: the total effectiveness score, the total score, and the effectiveness to cost ratio. The total effectiveness score reflects the expected overall effectiveness of the alternative; the alternative with the highest score is expected to be the most effective, without regard for implementability and cost. The total score includes cost and implementability considerations along with effectiveness. Therefore, an alternative that is very expensive and/or difficult to implement will have a lower total score compared to an alternative that is less expensive and/or easier to implement. The effectiveness to cost ratio is a measure of the cost-effectiveness of the remedy; a high effectiveness to cost ratio implies a cost-effective remedy.

Results for the Aniak WACS groundwater alternatives are summarized below.

- Alternative GW-3 (ISCO) received the highest effectiveness score, “10.5.” The second-highest effectiveness score was ERD with “9.8,” followed by MNA at 7.3 and Air Sparging at 7.0.
- Alternative GW-4 (ERD) received the highest total score, “13.8.” The second-highest total scores were Alternatives GW-2 (MNA) and GW-3 (ISCO) with “13.5.” Air Sparging has the lowest total score of 9.8, which interestingly was even lower than Alternative GW-1 (No Action).
- For each alternative, effectiveness to cost quotients were calculated for both the low-end and high-end of the cost range. The low-end quotients are used in the comparison discussion in this paragraph. Alternative GW-2 (MNA) and Alternative GW-4 (ERD) received the highest effectiveness to cost ratios, “0.60” and “0.57,” respectively. ISCO has an effectiveness to cost ratio of “0.49,” and Air Sparging has the lowest effectiveness to cost ratio of “0.39.”

Selection of a preferred alternative depends on the relative importance of the variables. GW-2 (MNA) and GW-4 (ERD) are the most cost-effective alternatives; ERD has a higher effectiveness than MNA, but the increased effectiveness is offset by its higher cost. If achieving cleanup in the shortest time is the most important factor, then Alternative GW-3 (ISCO) is preferred, although it is also the most expensive alternative. ISCO is expensive primarily because most of the oxidant will be used to treat the natural oxidant demand in the soil and groundwater (i.e., 72,840 kg $KMnO_4$ versus 8 kg $KMnO_4$ to treat the contamination). Air sparging has the lowest total score and effectiveness to cost quotient and is least likely to be considered the preferred alternative.

To evaluate the relative merits of MNA versus ERD (the two most cost-effective alternatives) at this site, a decision flowchart from the Interstate Technology Regulatory Council (ITRC) (ITRC, 2007) was used. The decision flowchart presents three criteria for consideration. These three criteria are listed below, with an interpretation of how the Aniak WACS site meets them.

1. Source and/or Primary Plume Treatment;

   The current understanding of the groundwater contamination at the Aniak WACS site suggests a plume of low-to-moderate concentrations that has not migrated significantly. Based on the plume geometry, there has been no distinct source and/or primary plume area identified in the saturated zone. The highest TCE concentration detected is 0.19 mg/L (almost four orders of magnitude below the solubility limit of 1,100 mg/L). It is possible that the mass of TCE released at the site is relatively small and mostly in the vadose zone; however, the site has not been adequately characterized to definitively state this.

2. Evaluate Plume Stability;

   a. Are the risks acceptable?
   b. Is the plume stable or shrinking?
   c. Are conditions sustainable?
   d. Is the remediation timeframe acceptable?
   e. Are the cost-benefits acceptable?

   The groundwater monitoring performed to-date is insufficient to definitively answer the five questions on plume stability. However, a preliminary analysis based on existing monitoring data suggests that the plume is stable or shrinking (i.e., no evidence of plume expansion). The risks due to drinking water appear to be acceptable, because there is no evidence of plume migration toward the existing drinking water wells. Risks due to vapor intrusion into the Aniak Middle School Building are not acceptable without vapor mitigation (i.e., SSD system), although the relative contribution of groundwater versus vadose zone contamination to the vapor intrusion pathway has not been determined. The sustainability of biodegradation over the expected life of the plume is something that cannot yet be determined. Current data suggest that there is an insufficient carbon source for significant reductive dechlorination plume-wide; however, the apparent plume stability suggests that attenuation mechanisms are acting to limit plume size. The acceptability of the remediation timeframe and cost-benefit analysis must be determined by the responsible parties and regulators.

3. Evaluate Enhancement Options.

Enhancement options (i.e., ERD) may be considered if the plume stability criteria are not met or as a contingency if future monitoring suggests that MNA is not progressing adequately.

Overall, it appears that additional plume characterization and implementation of the soil remedies would be beneficial before selecting a groundwater remedy. Additional plume characterization activities should include installing soil borings and monitoring wells east of the Aniak Middle School building, west of the building in the vicinity of SGP-17 and SGP-18, and in several other locations as needed to complete characterization of both plumes and the silt layer. MNA parameter monitoring should be performed at low water level. Microbial community testing for dehalococcoides organisms should be performed. Use of Bio-Trap® in-situ microcosms may be a cost-effective technique to assess the MNA potential, native microbiological community, and expected performance of substrate amendment. During the PCB soil excavation in the vicinity of the former septic tank and truck fill, soil samples should also be analyzed for TCE. If high TCE concentrations are detected in the silt at the base of the PCB excavation, direct treatment using a reductant (or possibly an oxidant) during the PCB soil excavation may be a very beneficial and cost-effective remediation strategy. Alternatively, depending on the location, magnitude, and extent of the TCE contamination and silt characteristics, installation of an engineered solution, such as placement of a gravel layer at the base of the excavation with distribution piping and a standpipe at the surface that could be used to deliver reagents periodically, may be warranted. Sampling details and a decision protocol should be incorporated into the excavation work plan.

Based on existing data, Alternative 2 (MNA) with Alternative 4 (ERD) as a contingency may be considered preferred. MNA would be expected to perform satisfactorily at this site if the following conditions (based on future characterization and planned soil remediation efforts to address the three ITRC criteria) are met.

1. Additional site characterization confirms that there is no distinct source/primary plume in the saturated zone. There is no evidence of free-phase or residual-phase TCE, and maximum groundwater concentrations remain three-to-four orders of magnitude below the solubility limit. The groundwater plume configuration is generally as outlined in this FS.
2. Additional groundwater monitoring supports the conclusion that the plume is stable.
    a. The groundwater plume is stable or shrinking, and there is no risk to the nearby drinking water wells. An alternative point of compliance can be established downgradient of the source area.
    b. The PCB soil excavation and SVE adequately address vapor intrusion risk (i.e., most of the contaminant mass is found in the vadose zone). Although volatilization from the silt layer/saturated interval below the silt layer may provide a continuing source for soil gas contamination, the level of continued volatilization is currently unknown and may be minor,

especially if the upper portion of the silt layer is directly treated during the PCB soil excavation.

c. Future VOC and geochemical parameter sampling indicates that there are zones or areas of highly-reducing groundwater in which reductive dechlorination of TCE is occurring at sustainable rates to adequately remediate the contamination over time

d. This alternative is deemed acceptable to ADEC and all of the interested parties.

3. If the above criteria are not completely satisfied, then it may be advantageous to implement ERD in a phased approach.

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FIGURES

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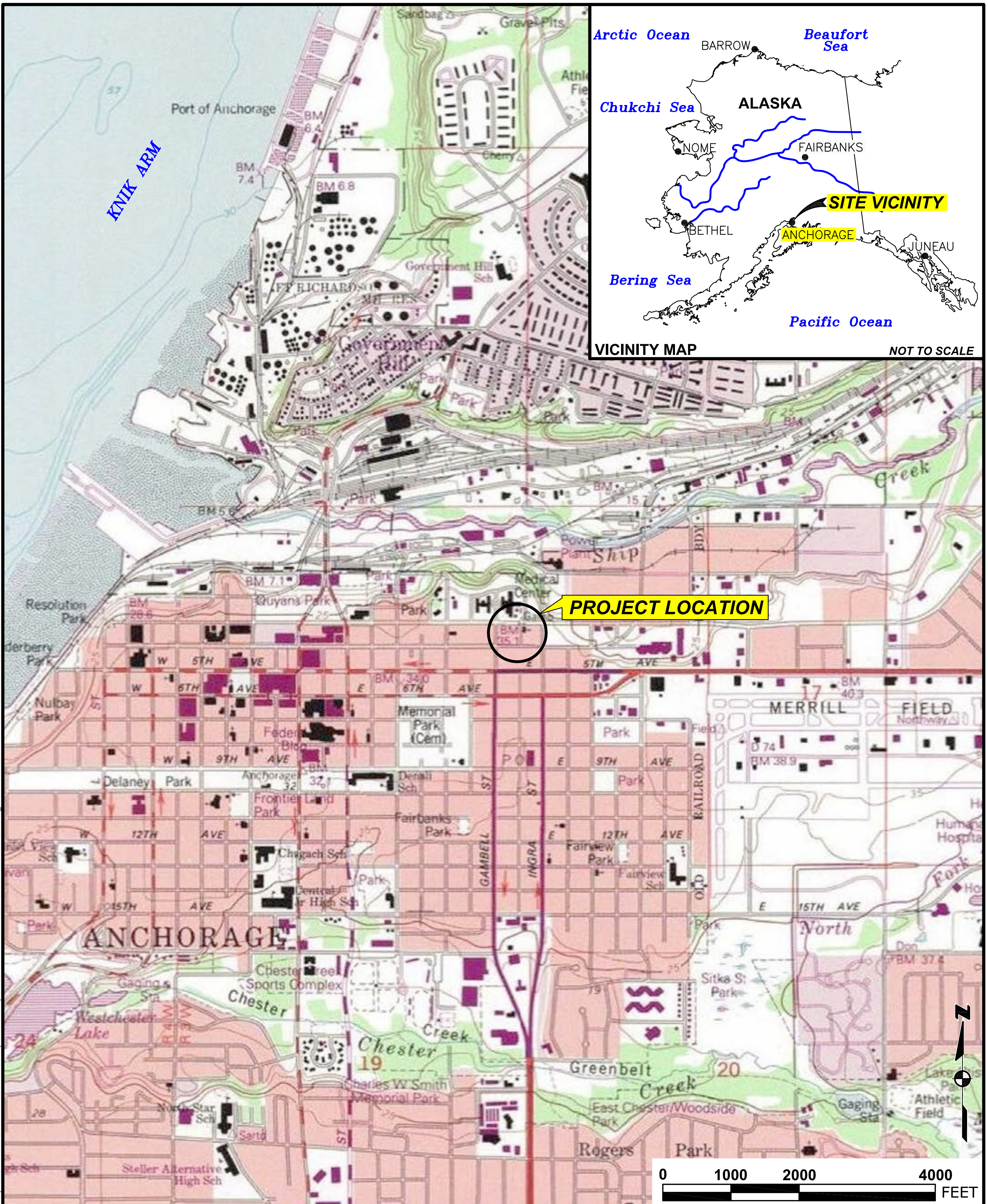


ERM

DATE: JUNE 2013
CHKD: T.M.
DRAWN: D.R.F.
PROJ. No.: 0168496

825 W. 8th Ave., Anchorage, AK 99501, (907) 258-4880

SITE LOCATION MAP

4TH AND GAMBELL
FOCUSED FEASIBILITY STUDY
Anchorage, Alaska

FIGURE

1

SOURCE: NATIONAL GEOGRAPHIC TOPO SOFTWARE PROGRAM 2007.

AREA GW 2/3 SUPPLEMENTAL GROUNDWATER INVESTIGATION

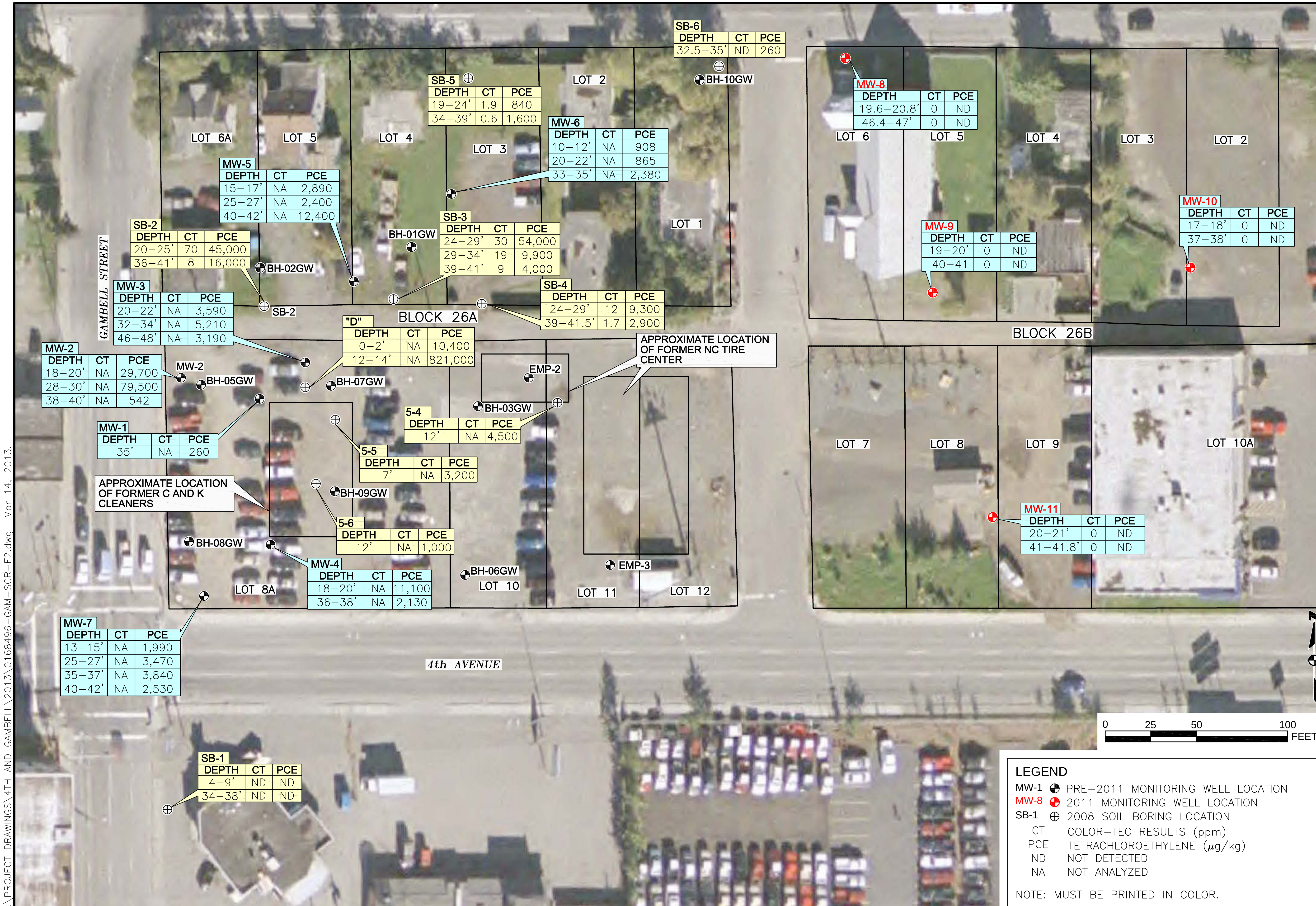
ALASKA RAILROAD CORPORATION
ANCHORAGE TERMINAL RESERVE
ANCHORAGE, ALASKA

Figure 2: GROUNDWATER POTENTIOMETRIC SURFACE MAP
JUNE 2008

ecology and environment, inc.
International Specialists in the Environment
Seattle, Washington

Date:
10/30/2008

GIS Analyst:



SOURCE: AERIAL PHOTO PROVIDED BY GOOGLE EARTH PROFESSIONAL 2008.

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FIGURE 2

1997 TO 2011 SOIL ANALYTICAL RESULTS

4TH AND GAMBELL
SITE CHARACTERIZATION REPORT
Anchorage, Alaska

DATE: MARCH 2013
CHKD: T.M.
DRAWN: D.R.F.
PROJ. No.: 0168496

825 W. 8th Ave., Anchorage, AK 99501, (907) 258-4880

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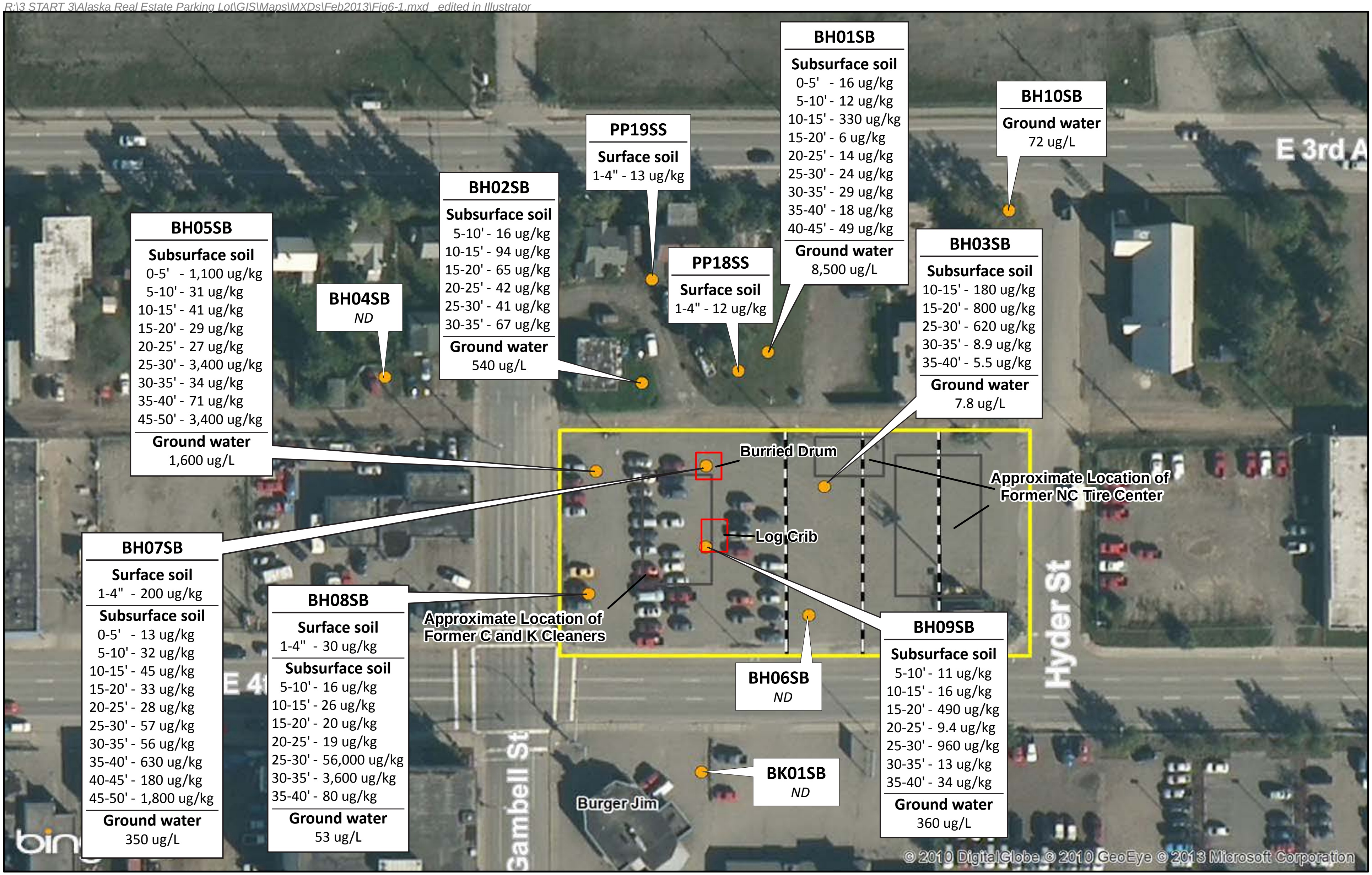

ecology and environment, inc.
Global Specialists in the Environment

N

0 25 50 100 150 Feet

Fourth Avenue and Gambell Parking Lot

Significant PCE Concentrations
July 2012
Anchorage, AK

Figure 6-1

Sample Locations
Site Boundary

ND Non Detect
ug/kg Micrograms per Kilogram
ug/L Micrograms per Liter

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ecology and environment, inc.
Global Specialists in the Environment

N

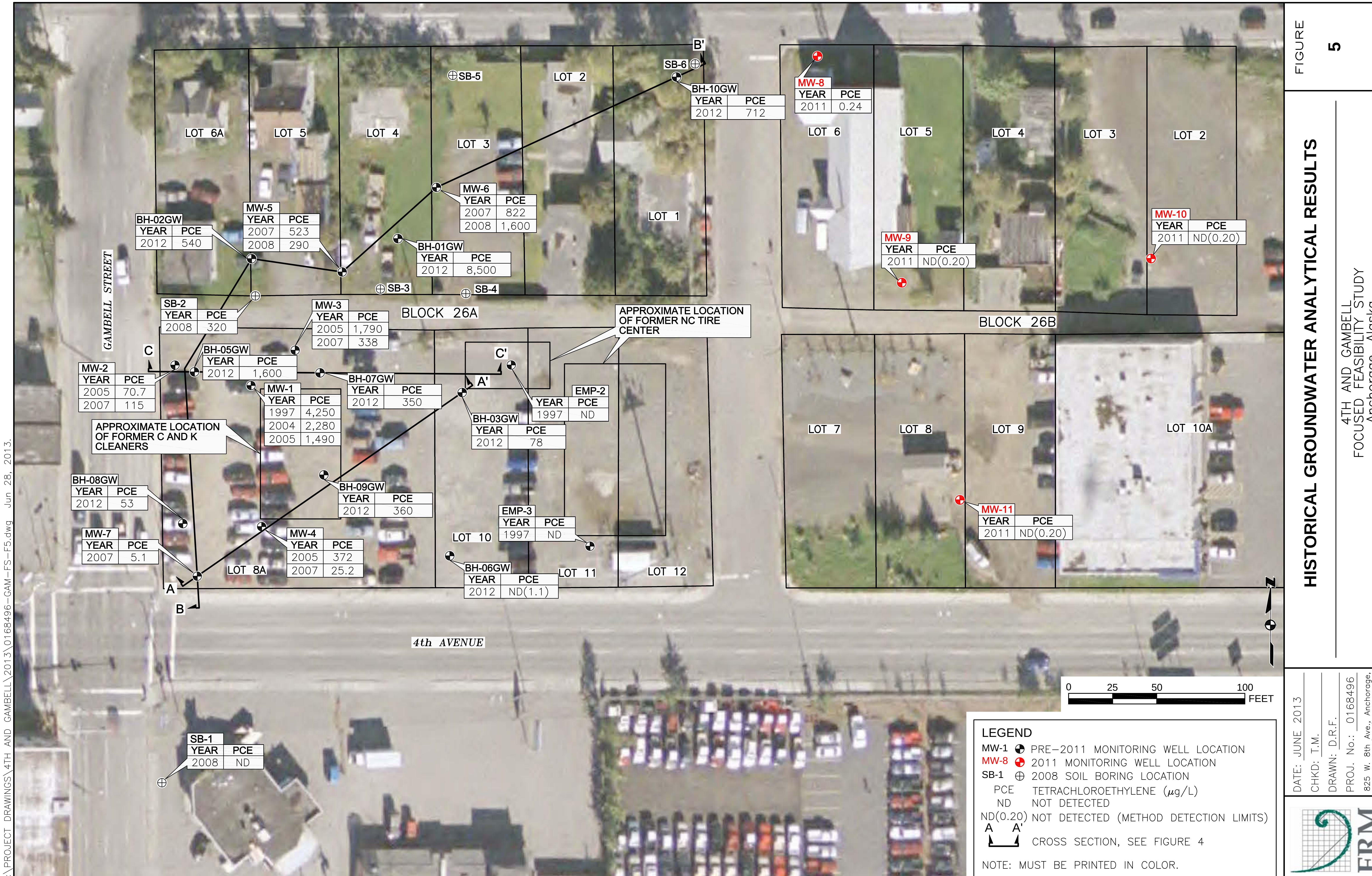
0 50 100 200 300
Feet

Fourth Avenue and Gambell Parking Lot

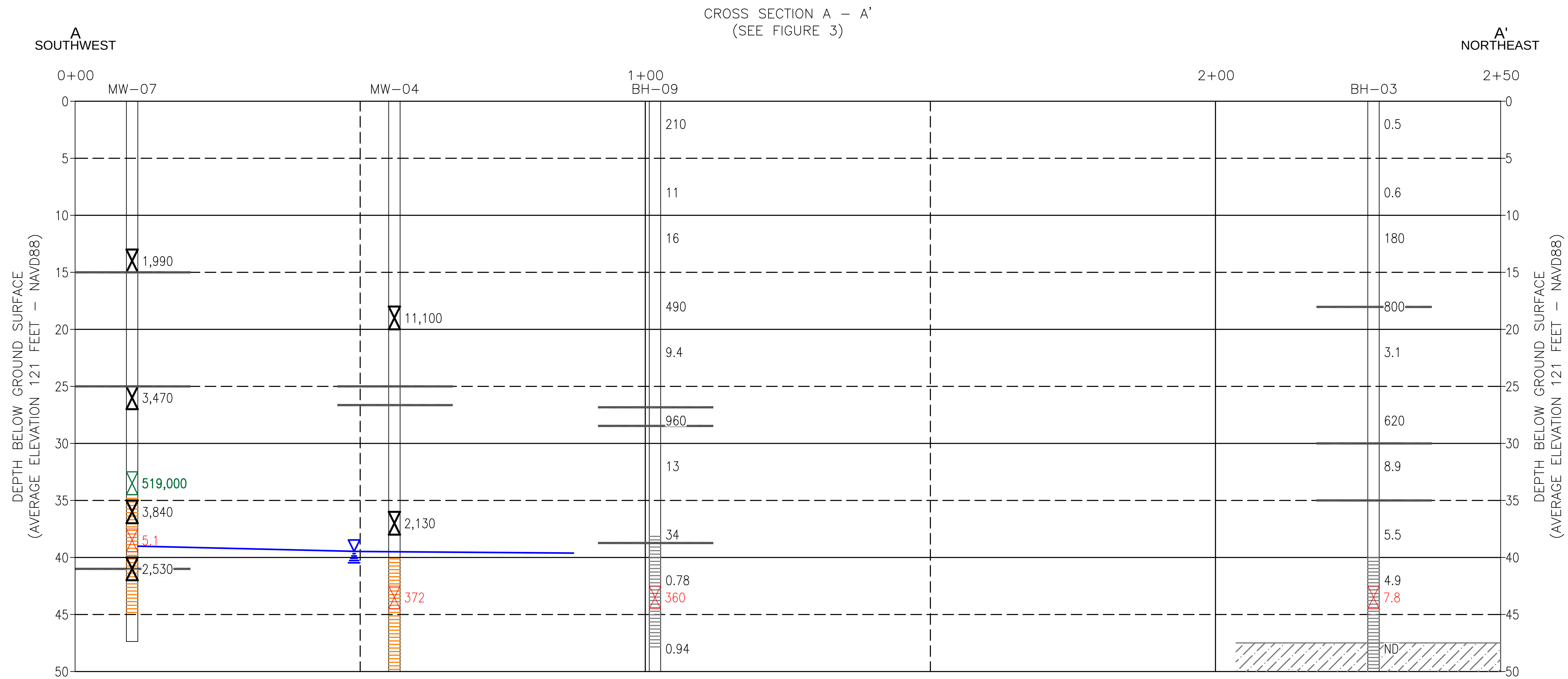
Significant PCE Concentrations
July 2012
Anchorage, AK

Figure 6-2

Sample Locations
Site Boundary
ND Non Detect
ug/kg Micrograms per Kilogram



SOURCE: AERIAL PHOTO PROVIDED BY GOOGLE EARTH PROFESSIONAL 2008.



LEGEND

2,530 PCE IN SOIL (μg/Kg)

2,530 PCE IN GROUNDWATER (μg/L)

2,530 TOTAL ORGANIC COMPOUND (μg/Kg)

PERMANENT WELL SCREEN

CLAY

GROUNDWATER ELEVATION

TEMPORARY WELL SCREEN

COAL SEAM

HORIZONTAL SCALE: 1" = 20'
VERTICAL SCALE: 1" = 10'
VERTICAL EXAGGERATION 2X

0 10 20 40 FEET

FIGURE 6

CROSS SECTION A - A'

4TH AND GAMBELL
FOCUSED FEASIBILITY STUDY
Anchorage, Alaska

DATE: JUNE 2013
CHKD: T.M.
DRAWN: D.R.F
PROJ. No.: 0168496

825 W. 8th Ave., Anchorage, AK 99501, (907) 258-4880

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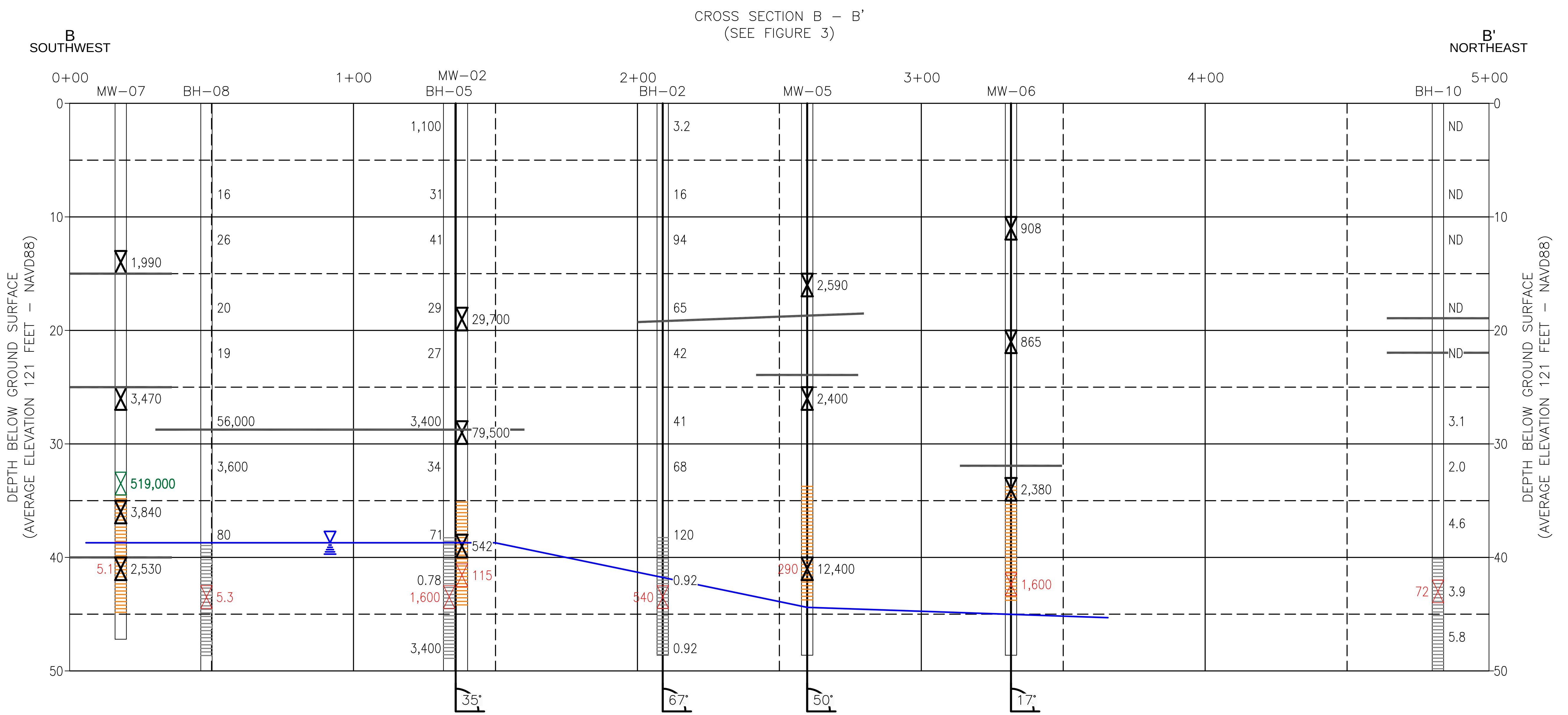

LEGEND

2,530 PCE IN SOIL (μg/Kg)

2,530 PCE IN GROUNDWATER (μg/L)

2,530 TOTAL ORGANIC COMPOUND (μg/Kg)

PERMANENT WELL SCREEN

CLAY

GROUNDWATER ELEVATION

TEMPORARY WELL SCREEN

COAL SEAM

90° DEGREE OF KINK IN CROSS SECTION IF GREATER THAN 10°

HORIZONTAL SCALE: 1" = 40'
VERTICAL SCALE: 1" = 10'
VERTICAL EXAGGERATION 4X

0 20 40 80 FEET

FIGURE 7

CROSS SECTION B - B'

4TH AND GAMBELL
FOCUSED FEASIBILITY STUDY
Anchorage, Alaska

DATE: JUNE 2013
CHKD: T.M.
DRAWN: D.R.F
PROJ. No.: 0168496

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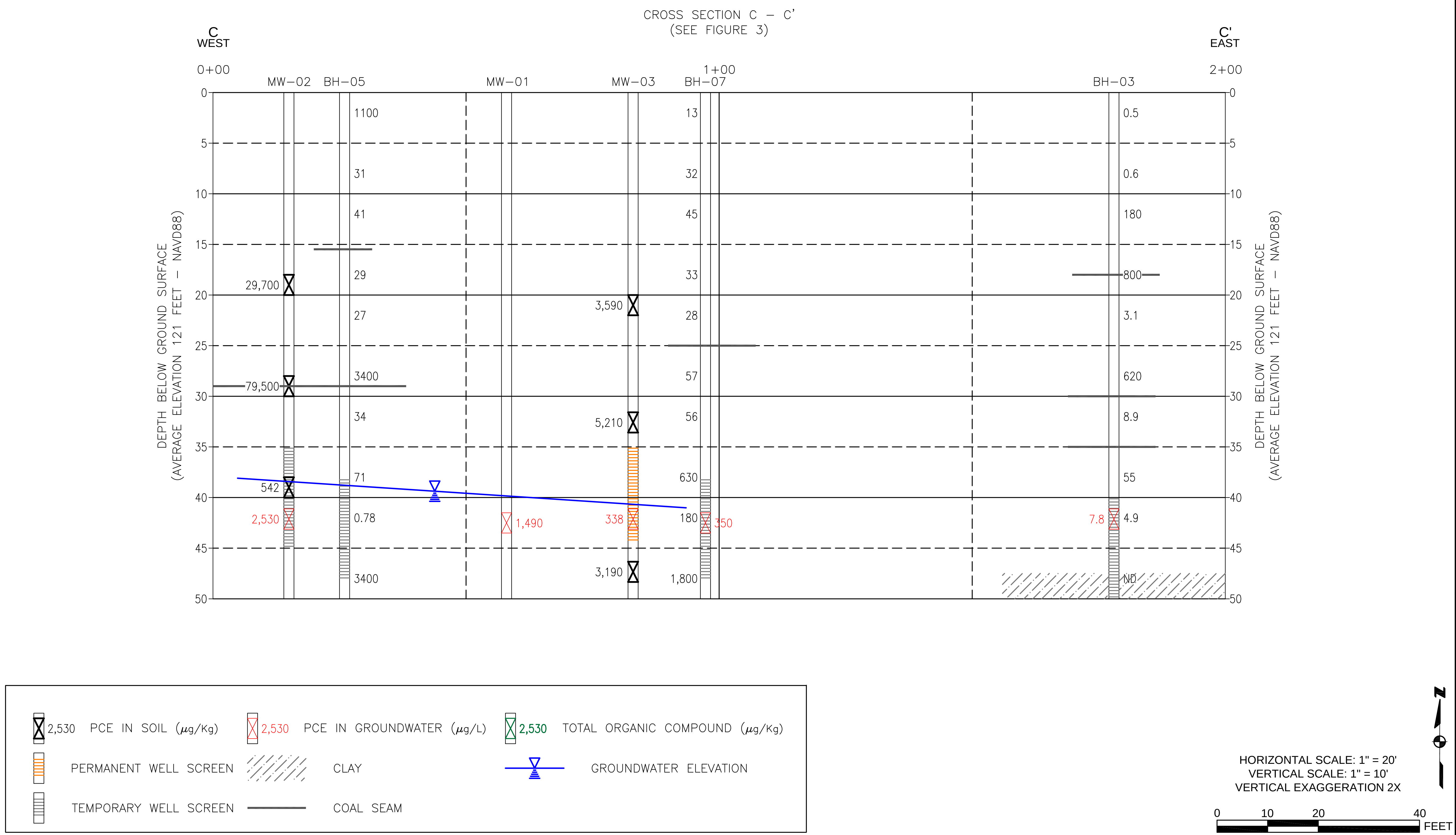

FIGURE 8

CROSS SECTION C - C'

4TH AND GAMBELL
FOCUSED FEASIBILITY STUDY
Anchorage, Alaska

DATE: JUNE 2013
CHKD: T.M.
DRAWN: D.R.F
PROJ. No.: 0168496

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APPENDIX A

Conceptual Site Model

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APPENDIX B

Feasibility Study Cost Estimate Spreadsheets

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APPENDIX C

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